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Instructional Design for Contextual Learning-Based Online Games

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https://doi.org/10.15017/1543990

出版情報：九州大学, 2015, 博士（芸術工学）, 課程博士
バージョン：
権利関係：全文ファイル公表済

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Instructional Design for Contextual Learning-Based Online Games

文脈学習に基づくオンラインゲームのための
インストラクショナルデザイン

テレス・ダ・シルバ・シルケル
Sylker Teles da Silva

２０１５年9月

TABLE OF CONTENTS

LIST OF FIGURES IV
LIST OF TABLES VI
ABSTRACT 1
INTRODUCTION 2
1. RELATED WORKS 10
2. CONTEXTUAL AND INSTRUCTIONAL DESIGN 13
2.1. VIRTUAL ENVIRONMENTS 13
2.2. DIGITAL GAME-BASED LEARNING 14
2.3. CONTEXTUAL TEACHING AND LEARNING 16
2.3.1. CTL AND VIDEO GAMES 17
2.4. INSTRUCTIONAL DESIGN 21
2.4.1. THE ARCS MODEL 21
2.5. THE ARCS-REACT APPROACH 24
3. PROTOTYPE DESIGN AND DEVELOPMENT 27
3.1. PROTOTYPING TOOLS 27
3.1.1. GAME ENGINES 28
3.1.2. MODELING AND ANIMATION 29
3.1.3. ADDITIONAL TOOLS 30
3.1.4. DEVELOPMENT WORKFLOW 30
3.2. STRATEGIC INTERFACE FOR DGBL 32
3.2.1. CARD GAMES OVERVIEW 32
3.2.2. CARD GAMES ANALYSIS 33
3.2.3. USER TESTS 38
3.2.4. RESULTS AND DISCUSSIONS 46
3.3. CHARACTER DESIGN 48
3.3.1. AVATAR CREATION AND CUSTOMIZATION 49
3.3.2. APPEARANCE ASPECTS 51
3.3.3. CONCLUSIONS 54
3.4. MATEMAGOS 54
3.4.1. GAME OVERVIEW 55
3.4.2. DESIGN METHOD 56
3.4.3. GRAPHICS AND VISUAL EFFECTS 58
3.4.4. GAME STORY 59
3.4.5. GAME STYLE 59
3.4.6. CORE MECHANICS 61

3.4.7. GAME USER INTERFACE 63
3.4.8. GAME CAMERA 66
3.4.9. SOUNDS AND HAPTIC FEEDBACK 67
4. PROTOTYPE USER TESTS 69
4.1. PARTICIPANTS 69
4.2. PROCEDURES AND INSTRUMENTS 71
4.3. DATA ANALYSIS 72
4.3.1. MAIN INVESTIGATIVE QUESTION 72
4.3.2. PLAYTIME AND SCORE 74
4.4. RESULTS 76
5. ARCS-REACT AND EDUCATIONAL GAMES 78
5.1. METHODS AND PROCEDURES 78
5.2. TOP EDUCATIONAL GAMES 80
5.2.1. ALGODOO 80
5.2.2. BRAIN AGE EXPRESS: ARTS AND LETTERS 82
5.2.3. DORA'S COOKING CLUB 83
5.2.4. KINECT NAT GEO TV 84
5.2.5. COOKING! RECIPES ON THE ROAD 85
5.2.6. MINECRAFT 87
5.2.7. MISSION US: A CHEYENNE ODYSSEY 88
5.2.8. MONKEY TALES: THE ABBEY OF AVIATH 89
5.2.9. NI HAO, KAI-LAN: NEW YEAR'S CELEBRATION 91
5.2.10. RE-MISSION 2 92
5.3. GAMES' ATTRACTIVENESS TEST 93
5.4. ARCS-REACT COMPARISON 97
5.5. EDUCATIONAL GAMES MARKET 100
5.6. CONCLUSIONS 101
6. FINAL CONSIDERATIONS 103
6.1. RESEARCH SUMMARY 103
6.2. CONCLUSIONS 105
6.3. FUTURE WORKS 107
AKNOWLEDGEMENTS 109
REFERENCES 110
APPENDIX A: GAME QUALITY QUESTIONNAIRE SHEET 120
APPENDIX B: USER TEST DATABASE TABLES 121

LIST OF FIGURES

Figure 1 Latin America Games Market (Superdata, 2014) 5
Figure 2 Research Methods 7
Figure 3 Motivation and Performance Relationship (Keller, 2009) ..23
Figure 4 Prototype Workflow and Tools 31
Figure 5 First Version of Game Prototype 31
Figure 6 Magic: The Gathering Cards 34
Figure 7 Yu-Gi-Oh Cards 34
Figure 8 Hearthstone: Heroes of Warcraft Cards 35
Figure 9 Might & Magic: Duel of Champions Cards 36
Figure 10 Baten Kaitos: Eternal Wings and the Lost Ocean Cards 36
Figure 11 Metal Gear Acid Cards 37
Figure 12 Card Deck of Famous Artists 40
Figure 13 High Contextual UI 41
Figure 14 Low Contextual UI 41
Figure 15 Participants Education 42
Figure 16 Participants Game Experience 43
Figure 17 Total Playtime 44
Figure 18 Pretest and Posttest Score 45
Figure 19 Game Score 46
Figure 20 Character Design Styles 51
Figure 21 Matemagos 55
Figure 22 Matemagos Screenshot 58
Figure 23 Final Fantasy IX Battle Scene 60
Figure 24 Core Gameplay Mechanics 61
Figure 25 Cards and Elements 62
Figure 26 Matemagos' Start Screen 63
Figure 27 Battle Screen Layout 64
Figure 28 Victory Screen 65
Figure 29 Game Over Screen 65
Figure 30 Game Camera Close Up 66
Figure 31 Audio Configuration Screen 67
Figure 32 Test sessions 69
Figure 33 Participants' Gender Distribution 70
Figure 34 Participants' Age Distribution 70
Figure 35 Average Individual Playtime 70

Figure 36 Subjects' Mathematics Score **73**
Figure 37 Mathematics score and game score correlation **74**
Figure 38 Game Score and Playtime Correlation **75**
Figure 39 Mathematics Exam and Playtime Correlation **76**
Figure 40 Algodoo Screenshot **81**
Figure 41 Brain Age Express Screenshot **82**
Figure 42 Dora's Cooking Club Screenshot **83**
Figure 43 Kinect Nat Geo TV Screenshot **85**
Figure 44 Cooking! Recipes on the Road Screenshot **86**
Figure 45 Minecraft Screenshot **87**
Figure 46 A Cheyenne Odyssey Screenshot **89**
Figure 47 Monkey Tales: The Abbey of Aviat Screenshot **90**
Figure 48 Ni Hao, Kai-Lan Screenshot **91**
Figure 49 Re-Mission 2 Screenshot **92**
Figure 50 Game's Most Attractive Features **94**
Figure 51 Player's Perception on Educational Game's Quality **95**
Figure 52 Top Educational Games **95**
Figure 53 Top Non-educational Games **96**
Figure 54 Educational Vs. Non-Educational Games **96**
Figure 55 Players' Reason for Choosing a Game **97**
Figure 56 Edugames' ARCS-REACT Score **99**
Figure 57 2011-2016 Worldwide GBL Growth Rates by Region **100**
Figure 58 Games Market Share By Platform **101**

LIST OF TABLES

Table 1 Engaged Learning and Game Design (Dickey, 2005) 15
Table 2: ARCS Model Major Categories (Keller, 2009) 22
Table 3 ARCS-REACT Heuristics Set 25
Table 4 ARCS-REACT Cards Analysis 38
Table 5 Contextual UI Hypotheses Summary 47
Table 6 MMOG Avatar Customization Features 52
Table 7 Ethnics Groups in Brazil 52
Table 8 Ethnics Groups in Brazil 53
Table 9 Technical Design Needs and Requirements 56
Table 10 ARCS-REACT Needs and Requirements 57
Table 11 Game Sound Features 67
Table 12 User Test Hypotheses 77
Table 13 Algodoo Learning Ratings (Sansing, 2014) 81
Table 14 Brain Age Express Learning Ratings (Bell E. , 2010) 82
Table 15 Dora's Cooking Club Learning Ratings (Healy, 2012) 83
Table 16 Kinect Nat Geo TV Learning Ratings (Sapieha, 2012) 84
Table 17 Recipes on the Road Learning Ratings (Matte, 2013a) 86
Table 18 Algodoo Learning Ratings (Sapieha, 2011) 87
Table 19 A Cheyenne Odyssey Learning Ratings (Matte, 2013b) 88
Table 20 Monkey Tales Learning Ratings (Koh, 2011) 90
Table 21 Ni Hao, Kai-Lan Learning Ratings (Healy, 2009) 91
Table 22 Re-Mission 2 Learning Ratings (Sapieha, 2013) 92
Table 23 ARCS-REACT Scale 98
Table 24 ARCS-REACT and Educational Games 99
Table 25 Games Comparison Hypotheses 102
Table 26 Main Research Hypotheses 105

ABSTRACT

In post-modern society technology is part of many people's lives. It became contextual for many children who have never known a world without Internet, who can't even imagine a place with no computers. Education is no exception to this marvelous universe. The work here presented proposes a game model to help students to contextually learn basic arithmetic operations and teachers as a complementary tool for the classroom. The study followed the principle that video games are educational by nature, even with no educational content in it; and used Contextual Teaching and Learning theory in association with Instructional Design principles to achieve the research goals. The basic problem that has guided the model proposal was the poor education quality in developing countries. Another problem pointed during the study was the fact that most games with educational purposes are low quality applications, poorly designed as games and working more as interactive supporting material. The approach followed was divided in three moments: a theoretical framework, a prototype development and user tests in a school in Manaus, Brazil. The prototype game called *Matemagos* was an arena battle game with a JRPG turn-based combat system. The prototype used a Trading Card-based User Interface to compose the command input system. For this experiment, 40 students were chosen from an elementary and middle school in Manaus, State of Amazonas, Brazil and randomly separated into treatment and control groups. After the test period of 30 days, the game sessions' data were sent to an online server and analyzed for statistical relevance and validation. The resulting analysis was intended to answer the main investigative question and research's objectives fulfillment based on a set of hypothesis. With all this information in hands, we could finally conclude that an Instructional Contextual Learning-Based Game can help improve children's education, specially in developing countries as these games can be developed with cognitive principles in mind, as the proposed model.

INTRODUCTION

Today's world is a complex mix of realities. The tangible universe is merging with digital environments faster each day and video games have an important part in this process. While the society has changed into a more connected global community, educators around the world discuss how the school and education can follow such lighting speed evolution.

In this battlefield are those who believe traditional education is still a better way to prepare the young to the world and those who has already embraced the new technologies as important tools for teaching and learning. In the middle there is the Contextual Teaching and Learning, a concept and method focused on the student and socio-cultural environments as any other constructivist approach.

This research is supported by the idea of using the technology and *immersiveness* of video games in combination with Contextual Teaching and Learning (CTL) to propose a better game interface based on Instructional Design principles, more fit to transmit information and promote education. It is a complex path to follow for its multidisciplinary nature. The challenge was quite welcome however.

In post-modern society, technology is part of many people's lives. It became contextual for many children who have never known a world without Internet, who can't even imagine a place with no computers. Education is no exception to this incredible universe, although the direction to follow is unclear. The work here presented proposes a game model to help students to contextually learn basic arithmetic operations and teachers as a complementary tool for the classroom. The study followed the principle that video games are educational by nature (Gee, 2007), even with no educational content in it; and used Contextual Teaching and Learning theory (Johnson, 2010; Crawford, 2001a; Sato, 2001) in combination with an Instructional Design model (Keller, 2009) as approach, because video games are part of children's lives and can be considered their context as much as a walk in a park.

The present study used the constructivism approach of education, more specifically John Dewey's experiential learning (Kebritchi, Hirumi, &

Haiyan, 2010) and Contextual Teaching and Learning (Crawford, 2001a; Sato, 2001) to propose a game model to help children in the understanding of basic Mathematics. Dewey's theory postulates that teachers and pupils must interact with the environment in order to build knowledge. Transported into the post-modern paradigm, this environment can well be an interactive simulacrum, i.e. a video game environment. CTL follows a similar concept adding the context element to the learning process. It means, in order to learn, students must create meaning by relating the content to their context in real-life (Johnson, 2010).

The development also used the Instructional Design model called ARCS (Keller, 2009) with the intention to create an environment capable of keeping players motivated in order to improve their performance. The ARCS approach in association with the REACT (Crawford, 2001a) model for Contextual Teaching and Learning theory composed a set of heuristics used as design requirements in the following prototype development.

The basic problem that has guided this study is the poor education quality in developing countries. Despite the proposed model could be applied in many different cultures and countries, Brazil was taken as an example of developing country in this research. According to the 2013 World Economic Forum (Zahidi, Bloom, Milligan, Guzzo, & Harding, 2013), Brazil has one of the worst educational levels in the world occupying the 88th position in a list with 122 nations. Also, according to UNESCO reporting on Education and Learning (UNESCO; EFA, 2014), in Latin America, only 70 in each 100 children are learning the basics in Mathematics.

As one of the most critical problems in Brazil's education, Mathematics was taken as learning material subject. In order to propose an alternative to countries like Brazil, this research relies on the following research question and hypotheses:

- *Can a Digital Game-Based Learning system based on Contextual Teaching and Learning and Instructional Design help elementary students to learn Mathematics?*

- *H_a1: Elementary students who will play the proposed game prototype will show a better performance on Mathematics exams than those who won't.*
- *H_a2: Elementary students' performance will be related to the game prototype.*

The present research aims to propose a conceptual model as a guideline to Digital Game Based Learning design and development oriented but not restricted to developing countries elementary students. In order to reach this goal, the following steps were performed:

- Define the key elements to an approach based on Instructional Design and Contextual Teaching and Learning theories;
- Create a guideline of development on top of the specified approach;
- Develop a Digital Game-Based Learning prototype;
- Test the prototype with elementary students.
- Compare the prototype with other educational games and with the proposed guideline;

Today's children context also comprehends technology and the digital world is also considered part of their real-life context, for the virtual is not opposed to the real (Lévy, 1998). In fact, the virtual world is increasingly the preferred reality nowadays, especially with device's mobility advances. In this context, video games are part of post-modern society as any other media and are great tools to improve students' achievement and motivation (Kebritchi, Hirumi, & Haiyan, 2010). Therefore, two hypotheses were raised to guide the work: teachers and students' interaction with a virtual environment can also be considered Dewey's experiential approach; and this same virtual environment can be considered students' context in CTL approach.

Despite its social and political problems, Brazil's game market is the biggest in South America with a total over $1.5 billion in 2014 and an estimate growth of $1.6 billion by 2017 (Superdata, 2014). Brazil is the

number one in western world for Social Networking Gaming with 36% of the Internet population playing at least once a week (NewZoo, 2013), but the Mobile Games are the largest game market in Brazil, with a total of $606 million in revenues per year (Superdata, 2014). The following chart summarizes Latin America Digital Game Market:

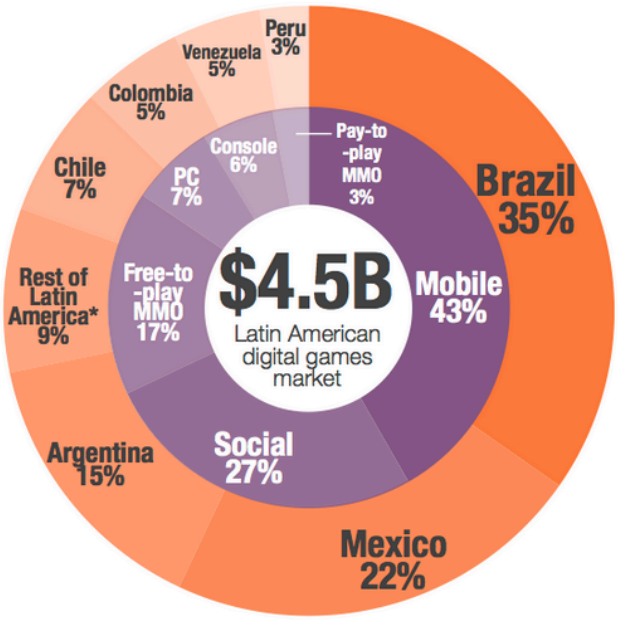


Figure 1 Latin America Games Market (Superdata, 2014)

With such a healthy video game market, Brazilian children may not have access to education with quality but certainly have access to online digital games. In this scenario, educational digital games can be an important tool to help educators and parents to enhance children's learning and stimulate kids to search educational content in video games more often. It may well serve as a model to other developing countries where education is poor, but technology market is growing fast.

Brazil is a South American country that occupies almost half of the continent's total area, with 8,547,403 square kilometers or 3,300,169 square miles (National Geographic, 2010). According to the Brazilian Institute of Geography and Statistics, Brazil's population was 190.732.694 people in 2010 and has passed the 204 million people in 2015 (IBGE, 2010). It's a huge country with some serious social political and social problems, including education.

An even more challenging scenario in Brazil is the northern region, the Amazon forest. The entire region covers eight countries: Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname and French Guiana[1], with 1.4 billion acres of dense forest, over 6,500 kilometers of rivers and 4.1 million square kilometers of Amazon basin, what represents 40% of Latin America and half the planet's remaining tropical forest (WWF, 2015; Butler, 2014).

In the middle of this amazing forest, there's Manaus, the city capital of the state of Amazonas, where this research was applied. In contrast with its surrounding jungle, Manaus is the largest Amazon city with 1.8 million people and 11.401 square kilometers (IBGE, 2010). As any developing country's large city, Manaus faces problems as chaotic traffic, demographic explosion and lack of infrastructure. Despite all this, Manaus Industrial Park is very developed and growing. It was made possible by government implementation of the *Manaus Free Trade Zone* in 1967, offering special fiscal incentives, i.e. taxes exemptions for industrial projects in the area (Bruha, 2014). Thanks to that, video game market is flourishing in the region as well, with many undergraduate courses, small game studios, technology institutes as Microsoft's INdT[2] and the first Samsung game studio out of Korea, the *Black River* (Reis, 2014; Carvalho, 2014).

In the other side of the planet there's Japan. Although this research was applied in Brazil, it was developed in Kyushu University, in Fukuoka city, Japan. This particular country was chosen because its historical importance on game industry. After the American game industry crash in 1985, it was the Japanese company *Nintendo* that brought back the golden age of video games with the *Nintendo Entertainment System*, called *Famicom*[3] in Japan (Wolf, 2007; Izushi & Aoyama, 2006). Hiro Izushi and Yuko Aoyama also points that Japan's video game industry success is related to creative skills linked to the culture of manga and anime in association with a competitive consumer electronics industry.

According to the *Geospatial Information Authority of Japan*, the archipelago country totals 377.962 square kilometers (as October 1, 2013) and

[1] An overseas French territory
[2] Nokia Institute of Technology
[3] Short for Family Computer

a population of 127.220.000 people as in January 1, 2014, according to the *Statistics Bureau, Ministry of Internal Affairs and Communications* (JapanGov, 2015). Japan has also a close relationship with Brazil, as many Japanese immigrants have arrived in the South American country in 1908 and later contributing with Brazil's development and culture (Masao, 2008); and the back way happens nowadays, with many Brazilians working on Japanese industry.

This work was divided in two parts: the main research and the complementary study and development (Figure 2). To accomplish the goals enumerated in section 2.2, a game prototype was developed and tested. This user test's results represents the output for the main research and used a true experimental, posttest-only design with control group and quantitative method to data collection (Meredith D. Gall, 2003). For this experiment, 40 students were chosen from an elementary and middle school in Manaus, State of Amazonas, Brazil and randomly separated into treatment and control groups.

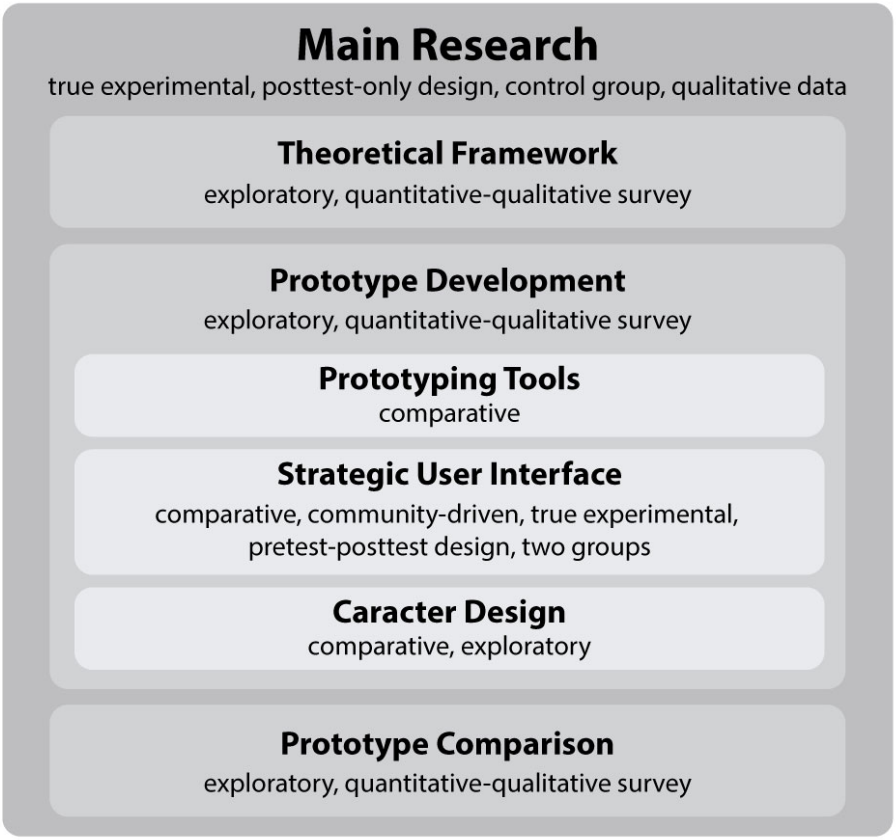


Figure 2 Research Methods

After the test period of 30 days, the game sessions' data were sent to an online server and analyzed for statistical relevance and validation. The resulting analysis was intended to answer the main investigative question and research's objectives fulfillment based on a set of hypothesis. In order to achieve these main research goals, complementary studies were necessary. They were divided in two parts as well: theoretical framework and prototype development.

The theoretical framework was grounded on exploratory research over the related bibliography and comparative methods towards the three principles used as research pillars: *Contextual Teaching and Learning, Video Games* and *Instructional Design*. The objective of this complementary study was to reach a model for the game prototype design and development that could support the main research goals of education and learning process.

For the prototype development study, four minor researches were conducted: prototyping tools, strategic interfaces, character design and prototype development. The brief description of prototyping methods and tools used a comparative method to establish the most viable and low cost tools suitable for fast development. This investigation resulted in a workflow model for character modeling and animation, image creation and processing, coding and sound editing.

The strategic interface for Digital Game-based Learning was a more complex study for the User Interface was considered a critical component of the game prototype. In this auxiliary research, a comparative method was used to analyze four *Trading Card Games* and two *Card-based Game Interfaces* in order to list categories and features related to the theoretical framework proposed. These features were used to develop a game prototype based on a community-oriented design approach. The prototype presented two different User Interfaces: one with 10 cards based on Art History and another designed with buttons instead. 20 Brazilian users tested the prototype during 3 days. A true experimental, pretest-posttest design research with two groups method was used. The objective of the user tests was to evaluate whether Card-based User Interfaces, also called Contextual UI, could be effective than traditional Button-Based UI, or Low Contextual UI, in help players assimilate information and consequently learn.

In the character development part, a comparative method was used to analyze three Massively Multiplayer Online games to establish a character design direction according to the proposed framework and with the target audience for the main research user tests. This study also used an exploratory research to find more information about Brazilian ethnics groups as to define a proper set of characteristics for the avatar in the final prototype. Additionally, a quantitative and qualitative survey was conducted with 60 Brazilian video game players to confirm the theoretical framework support for the final result.

1. Related Works

Before deal with the research goals and experiments, some related works were collected and analyzed in order to promote a better theoretical discussion about research's objects and define a starting point, a subject state from where this work could continue and contribute. In this sub-session there are some brief descriptions about these works divided in three main aspects of the present research.

Although the papers of James D. Klein and his collaborators are a relatively old work, they represent a very close research to this one, making them worth noting. In fact, Klein's work served as methodological basis and inspiration to the research here presented with due updates.

In the papers *Providing Practice Using Instructional Gaming: A Motivating Alternative* (Klein, Freitag, & Wolf, 1990) and *Effects of Using an Instructional Game on Motivation and Performance* (Klein & Freitag, 1991) the authors were able to determine the effects of games on undergraduate students' motivation using the 1983 instructional model ARCS (Attention, Relevancy, Confidence, and Satisfaction) for motivation and performance (Keller, 2009).

The experiment tested 75 psychology students in two groups. The treatment group subjects used an instructional game and the control group used a worksheet to practice information they received in a lecture two years before. By using Instructional Materials Motivation Scales or IMMS (Keller, 2009) with a posttest, the authors could measure students' performance and motivation. The authors have concluded that the instructional game had a significant effect on subject's motivation and performance.

Moving to a more recent work but keeping the subject there's the Ph.D. dissertation of Jason Bond Huett, (2006). Under the title *The Effects of Arcs-Based Confidence Strategies on Learner Confidence and Performance in Distance Education*, Huett took as research object the confidence component of Keller's ARCS model. The research goal was to improve undergraduate students' performance enrolled in an online course and test for unintentional effect on ARCS subscales, learners' motivation and instructional materials.

Huett studied 81 students during 5 and half weeks applying two qualitative surveys to measure confidence and motivation. He found that the treatment group showed statically greater gains in confidence outperforming the control group on all individual posttests regarding overall aggregate mean performance score. Upon his conclusions, the author supports the effectiveness of the ARCS model as tool for enhance students' motivation.

In the field Digital Game-Based Learning (DGBL) associated with instructional design models there's a coupe of works that has contributed greatly to this research. The paper of Jeng-Chung Woo entitled *Digital Game-Based Learning Supports Student Motivation, Cognitive Success, and Performance Outcomes* (2014) also investigates learners' performance under the light of *Motivation, Volition and Performance* (MVP) theory.

Woo investigated 63 university students during 8 weeks using an online game called *Operating a Small Factory in Computer-Aided Manufacturing*. By using *Instructional Materials Motivation Surveys* (Keller, 2009) and cognitive load and performance scales, the author found that motivation and cognitive load have a significant canonical correlation with performance and suggests that designers should increase motivation and cognitive load to enhance learning effectiveness.

In a similar work, Wenhao David Huang, Tristan E. Johnson and Seung-Hyun Caleb Han (2013) argue that excessive motivational and cognitive stimuli might overload students, impeding learning. In the paper *Impact of Online Instructional Game Features on College Students' Perceived Motivational Support and Cognitive Investment: A Structural Equation Modeling Study*, the authors investigated the relationship between game features, learners' perceived motivational support and cognitive investment.

As in the previously mentioned study, this research used the MVP theory to analyze 264 college students and point to three converging factors of DGBL characteristics: game appeal, game involvement and game structure. These game features have guided the present work in the prototyping development contributing significantly with the final results.

Based on each of these studies, the present work took a step further by combining theories from Instructional Design and Contextual Teaching and Learning in order to propose an Educational Game

Development Model. Many other authors have supported this research with mostly methodological approaches and theoretical models. They will be presented and discussed in the chapters ahead.

2. CONTEXTUAL AND INSTRUCTIONAL DESIGN

The long way this research has followed to reach its goals started with the theoretical framework about the complex relationship between education and virtual environments as valid tools for post-modern learning systems. This session is exactly about this discussion, starting with the principles of Contextual Teaching and Learning and Virtual Environments and then, stablishing a connection with video games and how such media can be used for educational purposes.

2.1. Virtual Environments

A recurrent terminology in this work is video game, not only as media or technology but also as concept, an environment of socialization and education. Before the following discussions relating video games with cognitive principles of Contextual Teaching and Learning and Instructional Design, the digital games themselves must be explored.

Digital games can be classified within Jean Baudrillard's (1995) definition of virtual environments, simulations mediated by technology, which bases have been constituted since the Classical Antiquity. The nature of such environments will be hereby discussed under the light of post-modern thinking, of historic-cultural man and his social interactions. The aim is to comprehend overall the relationship between subject and object inside such simulations.

Digital communicational ecosystems are a projection of a new society; born from a revolution, about what Castells (2001) dedicated a trilogy of books to explain and conceptualize. According to his work, our world and life has been changed by the globalization and by the new aspects of identity. The revolution of information and the restructuring of capitalism have created a new form of society.

Is possible to observe that such changes had happened by force of social and technological tendencies. Deep changes in human society that just left the Cartesian modernity of the machine-man making possible to transcend

the communication from a linear pattern to the connected society described by Castells.

It is understandable that as a new society emerges, a new culture arises as well by the simple observation on what happens every day in the world. This is the new culture of information, of computational communication and post-human, what Lévy (1998) defines as *cyberculture*. In his conclusions, criticizes who underestimates this social evolution by generalizing and put it in level of cultural restructuring of human kind.

Lemos (2008) adds to Lévy's ideas his own definition and origin to the cyberculture phenomenon, witch is complementary to the concepts already presented. According to the author, the contemporary culture associated with digital technologies is going to create a new relationship between the technic and social life. The author gives some examples such as cyberspace, real time simulations and virtualization processes.

The authors' notions suggest the meeting of technology and culture, a virtualization process started by post-modernity and facilitated by the advances in computing. In the cyberspace new societies are formed and the virtualization of artifacts and actions are completely assimilated by people.

It is exactly in the context of cyberspace societies that this research finds its way. These are the virtual environments where new interactions and relations of communications and culture take place. Video games are part of these environments. Not the only part, but a very popular one.

2.2. Digital Game-Based Learning

Play games is an activity older than men and therefore older than our culture and society (Huizinga, 1971). Play is a meaningful, ludic and irrational activity not restricted to human beings. Men and animals play for fun, but men have created technology and technology has changed the way we play.

Throughout human history, many kinds of games were created, based on cards, dices and boards (Bell, 1979; Hofer, 2003; Botermans, 2008). Computer advances since the late 1940s have broaden the possibilites of play. The first video game developed for entertainment, *Spacewar*, in 1962

(Donovan, 2010), has marked the beginning of a new media, with an essencial characteristic that has made all diffence: interaction.

Table 1 Engaged Learning and Game Design (Dickey, 2005)

ENGAGED LEARNING	GAME DESIGN

• Focused goals
• Challenging tasks
• Clear & compelling standards
• Protection from adverse consequences for initial failures
• Affirmation of performance
• Affirmation with others
• Novelty & variety
• Choice
 	
(Hall, 1998; Jones et al., 1994; Schlenchty, 1997)
	• Focused goas
	  o Narrative
	  o Character roles
	  ▪ Interaction with NPC and other players
	  ▪ Perspective
	• Challenging tasks
	  o Setting
	  o Action hooks (choice)
	  o Resource hooks (choice)
	  o Tactical and strategic hooks (choice)
	  o Time hooks
	• Clear & compelling standards
	• Protection from adverse consequences for initial failures
	  o Role-playing
	• Affirmation of performance
	  o Hooks
	• Affirmation with others
	  o Role-playing
	  o Nonplayer character
	• Novelty & variety
	  o Narrative arcs
	• Choice
	
	(Howland, 2002; Rollings & Adams, 2003)

Human-Computer Interaction has transformed not only the way people play, but all the everyday tasks in everyone's lives. However, it's not the only feature of a video game and certainly not the single one to make them suitable for educational content communication. A whole set of characteristics can relate a game to learning processes and this will be better explored in the next chapter under the light of Contextual Teaching and Learning model, but we can follow the study of Michele Dickey (2005) comparing and relating

engaged learning elements with videogame key features (Table 1) to better understand the nature educational nature of games.

There is no doubt about educational nature of digital games and its capability to engage students and keep them motivated (Gee, 2007; (Huang, Johnson, & Han, 2013), & Han, 2013) but which features are related to cognitive aspects of this engagement requires a further analysis. By comparing and relating popular video game features to engaging learning components, Dickey (2005) proposes that digital games can be used as models to instructional design in order to create a better media for interactive education. When video games and instructional design are combined for a more engaging and motivational system, the digital game-based learning (DGBL) arises (Prensky, 2001).

2.3. Contextual Teaching and Learning

The concept behind Contextual Teaching and Learning is quite simple: learning by doing. Of course this is a rough reduction of a process involving social constructivism and cultural-oriented learning (Crawford, 2001a, Johnson, 2010), but can serve well to demonstrate how physical classroom-only education is becoming less fit for CTL.

There are those who may say the classroom is all about contextual learning even before the CTL became a hot topic in education (Johnson, 2010), however, four walls and a teacher can do little to create context enough to fulfill the achievement of what CTL really proposes, although actual classrooms are becoming more and more equipped with multimedia assets and there are those who believe the future classroom will be even more hi-tech.

Multimedia classroom can give a more immersive environment to students, to be sure, specially compared to old blackboard and chalk standards, but that does not mean full contextualization. It can promote some level of contextualization and draw more attention, even improve outcomes (Turner & Farmer, 2008), but the multimedia classroom is not really a revolution. It represents just the evolution of the same principles that compose the vocational classroom. That evolution is bringing electronic boards and online classes for Distance Education (Deshpande & Hwang, 2001), but not real

changes in the way students learn nor in the teaching practices. Deeper changes are necessary to teach students who have more technology, immersion and contextualization in their mobile phones.

Some steps back are needed now for the objective of this section is far from change the paradigm of traditional education, but to propose a game interface. The motivation for this work, however, came from the same hard-to-brake paradigm that stands still in the education of many countries. It may be needed a dozen more papers just to start a discussion about what format should have a virtual classroom for Contextual Teaching and Learning for future generations, yet gamification of education seems to be a good beginning and a discussion already in place (Kapp, 2012); or even better than gamification: the game itself.

2.3.1. CTL and Video games

Games are a ludic activity and therefore have a lot in common to CTL. The very nature of play is directly related to the learning process (Huizinga, 1971). The learning process comes embedded in Video Games even though game designers don't have the intention to author an educational content (Gee, 2007).

Its built-in learning feature however, is not enough to state Video Games as CTL valid tools. A comparison between Video Games' characteristics and CTL principles may enlighten the question. According to Sato (2001), there are seven principles in context education approach as follows:

- Purpose,
- Building,
- Application,
- Problem Solving,
- Teamwork,
- Discovery,
- Connection.

Also, Crawford (2001a), states a set of five procedures called REACT:

- Relating,
- Experiencing,
- Applying,
- Cooperating,
- Transferring.

There are similarities and differences between the lists, but if we go deeper in each concept, it will be possible to establish connections between them. If these concepts can be related with games in general and consequently with video games, it will be safe enough to say that video games are well related to CTL as well.

Starting from the first list, *purpose* is about the meaning of doing something. The act of play is defined by Huizinga (1971) as a "significant function". Games are meaningful and the meaning of play is of contextual nature, for the play act is not only about the game itself but the sum of players' experiences (Salen & Zimmerman, 2004). That is what Crawford (2001a) calls *relating* in the second list above, i.e. "learning in context of one's life experiences or preexisting knowledge". Relating concept can be applied not only to video games but any other media for it represents the construction of meaning in a cultural semiotics perspective (Smagorinsky, 2001).

The meaning and knowledge carried by an individual are therefore, outcome of one's own experiences. Without experiences the individual is empty. *Experiencing* can be considered the most important part of the process of learning by context because it involves the prime principle of *learning by doing* (Crawford, 2001b). Therefore and furthermore, without experience or prior knowledge, CTL approach is not possible (Crawford, 2001a).

According to Crawford (2001a) the student's lack of experience can be solved with controlled experiences in classroom. Here the author opens *experience* in three more concepts: *exploration*, *discovery* and *invention* and

also describes three ways of accomplish experiencing through the use of *manipulatives, problem-solving activities* and *laboratories.*

By now we can say surely that *problem solving, teamwork* and *discovery* from Sato's (2001) list represents what Crawford (2001a) pointed as *experiencing*. It is not only the main concept to be part of CTL, but is also the core concept behind video games. Everything an individual does in life is experience of course, but interactive experiences are of more value to the learning matter (Falk & Dierking, 1999, 2000, as cited in Chang, 2006) (Ang & Zaphiris, 2008). The experience of watching a movie and playing a game are completely different and that distinction can be well translated as immersion.

Video games are all about experiencing and immersion. The very act of play implies interactivity (Salen & Zimmerman, 2004). They contain the problem solving aspect of it (Kong & Kwok, 2009) and are full of *exploration*, *discovery* and *invention*. As software they can be considered a *manipulative* as well. According to Crawford (2001a), manipulatives are objects or computer programs that allow students to build models of abstract concepts. The interactive and social feature of video games can furthermore classify them as laboratories in Crawford's approach, what makes video games meta-manipulative elements of *experiencing*. The multi layer of realities and overlapping experiences could be the most powerful tool of learning in context in comparison with the traditional classroom. But this is evidently a hypothesis yet to be discussed in further works.

Applying can be found in both lists, and is subsequent action of *experiencing*. Crawford defines it as "learning by putting the concepts to use" (2001a). In a very simple way, applying is experience again, but this time, knowing what to do. The success of application can be motivating or frustrating. It cannot be too easy or too difficult to accomplish (*op. cit*.). That takes us to an important aspect of game design: challenge.

Good games are long, difficult and challenging, but also "pleasantly frustrating" (Gee, 2007). The author defends that a key to design a good game is make a hard task very pleasant and life enhancing in a way people keep doing it. If they fail, they go back and try it again until the

learning process take place and the task is successful accomplished with a rewarding feeling.

Next, there is the *cooperating* aspect of Crawford's (2001a) REACT. It can be also related with *teamwork* and *connection* in Sato's (2001) list. In fact, the *cooperating* or *sharing* is a point present in the *experiencing* and *applying* when it comes with work in groups. It is true that no every game carries cooperation, but especially after the Internet, almost every game has the capability to share. Game experiences are shared all over the world through videos, images and invites to play. When it comes to cooperation, many games offer the multiplayer option online and offline. In that sense it may be that the Massively Multiplayer Online Games (MMOG) represent the most cooperative of games, with its thousand of players sharing the same simulacrum and experiences in a synchronous and persistent environment (Kong & Kwok, 2009).

In order to advance in a MMO game, the player must engage in a collaborative learning process (*op. cit.*). It means socialize and cooperate in order to learn (Kwok & Khalifa, 1999, as cited in Kong & Kwok, 2009). Lone gamers can have a hard experience by trying to advance in a MMOG. Most of times players must form small groups to overcome challenging *dungeons* or bigger ones to accomplish difficult *raids* or even more organized associations as *guilds* which members can better cooperate and share (Nardi & Harris, 2006).

Collaborative learning also comprehends knowledge transfer, the last element of Crawford's (2001a) list. Among the four ways of knowledge conversion proposed by Nonaka in *A Dynamic Theory of Organizational Knowledge Creation* (as cited by Kong & Kwok, 2009), *externalization* is the most suitable in the sense of what Crawford (2001a) suggests. *Externalization* represents the conversion from tacit knowledge to explicit knowledge, i.e. from what is embedded in game as specific skills, strategies and is difficult to transmit or share by formal language to what is written in the game's language and can be easily sharable with other players (Kong & Kwok, 2009). According to the authors, the experienced players tend to share their knowledge with beginners, and that is what *externalization* means and also what transferring is about in CTL context.

At this point is plain to see that games in general (including Trading Card Games) and video games are not only related with Contextual Teaching and Learning but also can be turned in a proper tool for current and future generations of students or learners. Furthermore, Online Games offer the best environment to apply the CTL concepts and promote a technology-mediated collaborative learning. Is now secure to move on with the section's goal and use the points here discussed to propose a game interface to fit the CTL approach using Instructional Design as model.

2.4. Instructional Design

The very well stablished field of study known as Instructional Design (ID) or design of instructions can be defined as "the science and art of creating detailed specifications for the development, evaluation, and maintenance of situations which facilitate learning and performance" (Richey, Klein, & Tracey, 2010). This definition has changed throughout the decades since the 1960s (*op. cit.*) as the educational technologies have changed as well. Looking into the educational technology definition established by the AECT (Association for Educational Communications and Technology) in 2008 we will find some similarities with the ID definition: "Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources." (Reiser & Dempsey, 2011). The two main similarities found in these concepts are learning facilitation and performance improvement. By relating the learning technologies with the Instructional Design we can understand them as a whole field of design focused on planning strategically a technology for education.

2.4.1. The ARCS Model

As a theory, Instructional Design is supported by many conceptual models, i.e. processes description of decisions, activities, design thinking, team interactions, architecture, documentation, etc. (Gibbons, Boling, & Smith, 2014). These models provide guidelines to ID technologies creation

and development assuring a much more reliable approach for this study proposition. Among the ID models available in Instructional Design Organization Website (2013), the ARCS approach was chosen according to the following criteria: have something in common with game design development approach. The ARCS approach (Keller, 2009) is a design model described in a set of studies of John Keller in the 1980s. It is strongly based on the motivational design, a core concept in game development. Players are often motivated in a variety of ways, including but not restricted to social interaction and knowledge (Rouse, 2004; Novak, 2011), base concepts of constructivist educational theory present in Contextual Teaching and Learning approach also used in this work.

ARCS is an acronym for its four basic categories: *Attention, Relevance, Confidence* and *Satisfaction* and can be defined by process questions:

Table 2: ARCS Model Major Categories (Keller, 2009)

MAJOR CATEGORIES AND DEFINITIONS		**PROCESS QUESTIONS**
Attention	Capturing the interest of learners; stimulating the curiosity to learn.	How can I make this learning experience stimulating and interesting?
Relevance	Meeting the personal needs / goals of the learner to effect a positive attitude.	In what ways will this learning experience be valuable for my students?
Confidence	Helping the learners believe / feel that they will succeed and control their success.	How can I via instruction help the students succeed and allow them to control their success?
Satisfaction	Reinforcing accomplishment with rewards (internal and external).	What can I do to help the students feel good about their experience and desire to continue learning?

Each one of these categories had evolved alongside the model itself since its first introduction in 1984 and represents the major dimensions of human motivation, more specifically learning motivation (Keller, 2009). According to the author, the model is a tool of strategy creation focused on motivation, stimulation and sustainability in each of the four categories.

The author continues stating that motivation is multidimensional, composed and influenced by culture, social interactions, physical and virtual environments, therefore is plausible to deal with motivation in a system perspective. This very multidimensional nature, however, stands as a great challenge as well. Due to its nature, motivation can be very unstable with huge changes in intensity and performance over short periods of time. John Keller (2009) explains that this variation have a curvilinear association with performance, as shown in the following graphic:

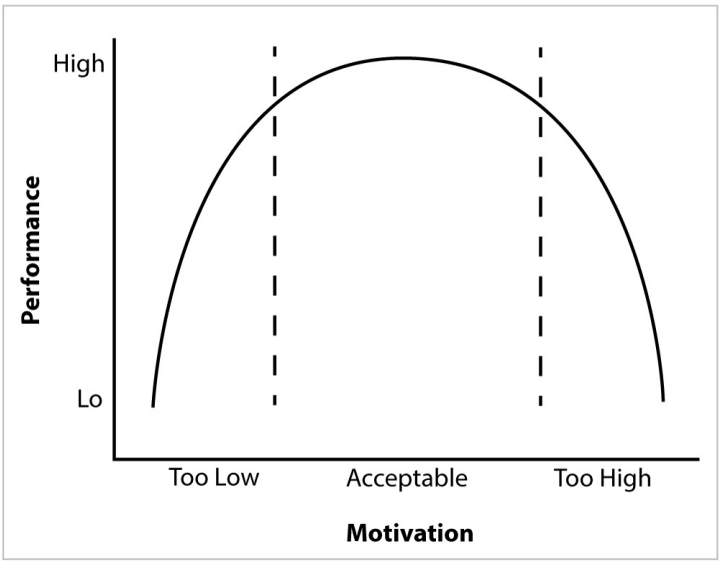


Figure 3 Motivation and Performance Relationship (Keller, 2009)

Following this motivation-performance curve, it is clear that motivation cannot be too low nor too high resulting in low performance issues either case. It can be a problem using this approach with digital games because its immersive feature, responsible for its great potential in post-modern education, is also responsible for excessive motivational and cognitive stimuli (Kiili, 2005; Huang, Johnson, & Han, 2013). The authors established a relationship between digital game-based learning features and motivation based on ARCS model suggesting that game designers should pay extra attention to game features that could demand too much from students' cognitive processing capacity.

Another problem pointed by Keller is the measurement of motivational design elements, such as human motivational characteristics, design strategies, social and environmental conditions and consequences.

Most of times, measures of effort are used, as they are easier than achievement measures, what is in turn indirect and subjective.

2.5. The ARCS-REACT Approach

Understanding ARCS (Keller, 2009) as a holistic system approach facilitates an interaction with similar conceptual models, as Contextual Teaching and Learning's REACT (Crawford, 2001a) discussed before. Despite of its origin in educational theory, Instructional Design has changed towards an *instructional theory* itself (Tennyson, 2010). Nevertheless, these theories are not exclusive. In fact, Tennyson states that there's a fundamental improvement of ID by combining it with educational foundations. Following that direction, this work proposes a combined approach in order to define guidelines for the prototype development. It is important to note that the present study does not intend to investigate whether this ARCS-REACT model is effective on game designing or in the learning process, although it can be an interesting future work.

The ARCS-REACT model was built over two sets of playability heuristics (Nielsen & Molich, 1990; Rogers, Sharp, & Preece, 2011). The first set combines the major categories of the ARCS model and the studies of Koeffel et al. (2010) and Paavilainen (2010) upon the works of Federoff (2002), Desuvire et al. (2004) and Röcker and Haar (2006).

The expected results by using the ARCS heuristics set in the prototyping implementation is to have a game capable of sustain player's motivation and performance. The game mechanics explained later in this work was oriented by these principles. However, there are some videogame features more related to player's interaction and socialization and for those, the Contextual Teaching and Learning models were used.

This way, the second set relates the CTL principles of REACT (Crawford, 2001a) with social games heuristics by Paavilainen (2010) for Contextual Teaching and Learning is directly connected with socialization and the evaluation model described by Sweetser & Wyeth (2005). Similarly to ARCS, these principles have guided the game design and helped in the decision making process regarding some playability aspects, as difficulty level

and fun factor. The table 3 shows each one of the ARCS-REACT categories, its description and the heuristic sets:

Table 3 ARCS-REACT Heuristics Set

Attention	Capturing the interest of learners stimulating the curiosity to learn.	• Get the player involved quickly and easily; • Create a great storyline; • Should use visual and audio effects to arouse interests.
Relevance	Meeting the personal needs / goals of the learner to effect a positive attitude.	• Provide clear goals, present overriding goal early as well as short-term goals throughout play; • Players discover the story as part of gameplay; • The game transports the player into a level of personal involvement emotionally;
Confidence	Helping the learners believe / feel that they will succeed and control their success.	• The Player has a sense of control over their character and is able to use tactics and strategies; • A player should always be able to identify their score/status and goal in the game; • Player should be given controls that are basic enough to learn quickly; • Players do not need to use a manual to play game.
Satisfaction	Reinforcing accomplishment with rewards (internal and external).	• The game is enjoyable to replay. • Make the player feel accomplishment in every play session; • The player should receive meaningful rewards;
Relating	Learning in context of previous experiences or preexisting knowledge.	• Use common and familiar themes from popular culture which can be understood easily; • The game interfaces and mechanics should be easy to learn and use. • Learning the game should not be boring, but be part of the fun.
Experiencing	Build new knowledge with practical experiences.	• Players should be able to start playing the game without reading the manual; • Provide players with new, evolving content and offer an emergent game world; • Players should feel emotionally involved in the game;
Applying	Put the created knowledge to use in new problem solving activities.	• Challenges in game must match the players' skill levels; • The level of challenge should increase as the player progresses;
Cooperating	Work in groups to handle complex problems.	• Use social contacts as assets in the game and make them part of the game mechanics; • The game should support competition and cooperation between players; • Provide high-score lists for competing with friends;
Transferring	Transfer the acquired knowledge to other students.	• Provide means for players to share information and in game resources; • The game should support social interaction between players;

Those tested heuristics were used as design needs and requirements (Hartson & Pyla, 2012) for the prototype development. Users

tests were applied in some of the development steps in order to assure a consistent design with the proposed model and to correct eventual misdirection in the project progression. The resulting prototype was tested with 40 Brazilian students and compared with other educational games as well. The design, development and user tests will be demonstrated in the next chapters.

3. PROTOTYPE DESIGN AND DEVELOPMENT

This section will address the game prototyping, its methods and procedures. It starts with a heuristic model proposal to guide the game design and development and goes through the prototyping tools, interface design and final prototype conception. A fast prototyping method was intended in order to finish the game in time for the user's evaluation, the most important part of this study.

The interface design was directed towards a Trading Card Game-based system and a user's test was performed to validate this design orientation. In the end, a Mathematics game prototype was developed. The *Matemagos* game combines the traditional Japanese RPG style battle system with a card-based interface delivering a simple game mechanics based on basic Mathematics operations.

3.1. Prototyping Tools

Game prototyping is a very common activity among game designers searching for founding and academic researchers trying to achieve their experiment's goals. Although some simple games require just few hours to get its prototype fully functional, others demand a very long time, in most cases, impossible to accomplish with limited budget and human resources. Complex systems as the DGBL proposed in this work even with a couple of game's quests require a great effort and team working to get everything done on time. In case of academic researchers, time and money are very limited and controlled resources. Also, a research student often develops everything, from design to programming, by himself.

In an attempt to mitigate this problem, some low cost and free game design and development tools were tested during the development of the first prototype version. The goal in this section is to find the fastest and cheapest way to develop a game prototype and document it in a way other researchers and developers can follow or improve. It is worth note that these studies were performed in the beginning of this research, about two years

before the date of publication; consequently, most of the technologies and services here described are outdated but nevertheless useful for the development achieved.

By using a comparative method (Rihoux & Ragin, 2008), some of the most popular game engines, 3D modeling software and animation services were evaluated based on a cost versus quality criteria. The time of development offered by the tool's workflow was also considered and platform compatibility as well.

3.1.1. Game Engines

The first round was given between the game engines *Unity*[4] and *UDK*[5]. Both offer free versions and are powerful enough to create AAA games despite of not being listed among the impossible expensive engines like *CryEngine*[6] and the richer sister of *UDK*, *Unreal Engine 4*[7].

Flexibility was decisive here. While UDK only uses its own C-like script called *UnrealScript*, Unity games can be written in C#, Boo and the Javascript-like *UnityScript*.

Another significant aspect if not the most important was the target platforms. Unity can one-click publish games to a wider variety of platforms from Web Browsers to mobile, going through the three main operational systems in market the top video games consoles. Also, Unity is available for both Windows PC and Mac OX while UDK can run only under Microsoft's OS (Menard, 2011).

The licensing was also compared. UDK have a confusing EULA for beginners. It's free for non-commercial projects and costs US$99 per title and 25% royalty on revenues above US$50.000. Unity's free version can be used for commercial purposes without royalties. It only lacks some features and target platforms available for Pro version users only. The Unity Pro costs US$1500 and likewise do not require royalties.

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[4] Unity Technologies
[5] Epic Games Inc.
[6] Crytek
[7] Unreal Engine 4 was made free at the end of this study and Unity 5 released a Personal License with all Pro features for free as well. This latter version was used to complete the prototype development.

One last consideration about these two great engines: plugins and add-ons. UDK comes with great editor's tools like Kismet for graphical scripting and Matinee for animation just to mention a few (Thorn, 2011). Unity's Asset Store offers a huge stock of resources created by users to turn the game development as fast as possible. Some assets are free and most of them are very low priced from 3D models to sounds.

3.1.2. Modeling and Animation

There are plenty of free modeling and animation tools nowadays. Blender[8] is one of designers' favorite and is very well supported with a very active community. But those once considered unreachable for most independent artists because of the high cost have now free licenses for students: the Autodesk software[9].

Maya can run under Windows and Mac OS while 3DS Max is only available for Microsoft's operational system. They are powerful and very different in the way of use and Unity can import assets from both of them and Blender as well.

In the end, it doesn't really matter which modeling and animation tool was used if the results are good enough. Besides, the best software is the one you know better (Mastri, 2006). However, some tools can really rocket lunch the development time, specially concerning modeling of humanoid characters, like *MakeHuman*[10] and *DAZ3D*[11].

MakeHuman is completely open source and very easy to learn and use. It can export the mesh for most of 3D software available and game engines as well. During the tests, the MakeHuman generated mesh showed some imperfections, and needed to be cleaned up in another 3D tool like 3DS Max or Maya before importing to Unity. Besides, the low poly mesh generation, an important feature when talking about game development, did not offer many options for configuration, as quality and polygons count, for instance.

[8] blender.org
[9] students.autodesk.com
[10] makehuman.org
[11] DAZ Productions Inc.

DAZ3D is a former paid humanoid modeling tool that is now free. Similar to *MakeHuman*, it works by importing models and packages, but as an older application in the market, there are much more content available for DAZ3D. Unfortunately, most of those assets are paid. The free material however is a very good start.

The generated mesh in DAZ3D revealed a superior quality compared to *MakeHuman* and some plugins helped to prepare a 3D character more suitable for games, like *Decimator*, for instance, that creates low poly meshes with many important options to control the end quality. Another interesting tool for DAZ3D is the Texture Atlas that combines all models texture into one single image file, much more lightweight for real time applications as digital games.

Alongside with 3D modeling software, some animation services may come in hand to accelerate the game development process, like *Mixamo.com*. It offers a large variety of services and tools like motion capture and packages of characters and animations. A student plan can grant access to all services and tools for US$200.

3.1.3. Additional Tools

Game development is a very complex and multidisciplinary task (Fullerton, 2008) and fortunately, the University can provide some tools as well. The Sound design and image processing, for instance, wasn't tested for the Adobe Creative Suite provided could handle it with Photoshop, Illustrator for images and Audition for music and sound effects, although the open source Audacity was also used when outside the laboratory for sounds. For coding, scripting and debug, the Unity's *MonoDevelop* was used.

3.1.4. Development Workflow

After six months of tests and development of the proposed prototype, it was defined the best workflow with the given applications in Figure 4, listed in order of use. The chosen software for its flexibility and quality versus time of development can be checked in the same figure.

Additional assets were largely used from both Unity Asset Store and DAZ3D store in order to speed up the development. The asset's cost had an average price of US$15.

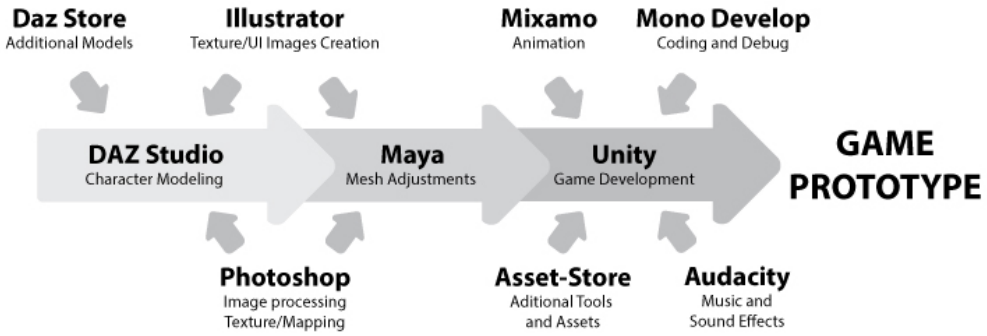


Figure 4 Prototype Workflow and Tools

The resulting game prototype can be seen in next figure, composed by four character models from Unity Asset Store with clothes modeled in Maya as well as the dungeon environment.



Figure 5 First Version of Game Prototype

The enemy dragon was created in Daz Studio and adjusted in Maya. All animations were imported from Mixamo.com and all textures and User Interface elements created with Adobe Illustrator and Photoshop. The workflow and tools described here were used to build the final prototype with a satisfactory development curve.

The figure above reveals that a card-based Interface was created in the game prototype. It is part of the development strategy and approach regarding the best way to communicate with user in the ways of ARCS-REACT requirements and will be explained in the next section.

3.2. Strategic Interface for DGBL

Playing Cards can carry much more information than buttons and icons, are more visual appealing and highly contextual. Based on this hypothesis, Trading Card Games were used as basis for design and development of the Digital Game-Based Learning prototype.

A user and community directed design method came in hand to create and develop the game context, essential in CTL process. 10 cards based on Art History were created and a similar interface was designed without cards, as user test control element. 20 Brazilian users tested the prototype during 3 days.

This section followed two paths in order to turns into one that shows the expected results. There are some explanations about Card Games and Contextual Teaching and Learning presented in the first two topics followed by the interface proposal itself and the results.

3.2.1. Card Games Overview

In order to better understand the game design process in which this section is engaged, a look into the card games concept and history is necessary. Also the motivation that had lead this work in the choosing of card games as interface of study and its relation with education and learning deserves an explanation as well. Of course it is not the objective of this work to dig deep in the matters of history, especially of such an ancient artifact as playing cards, but some events may be useful to the understanding of further assignments.

Despite its obscure origin, it is possible to trace the European early card game from the fourteenth century onwards, probably coming from the East (Benham, 2013). Theories vary from Asian tablets and discs coming from

chess to the further introduction into Europe by the Saracens through Spain. Benham suggests however, that the European playing cards are distinct and original in its conception and as the timeline of Oriental games is doubtful, there's a good chance of these games been created at same time in different cultures, including the Tarot and its Egyptian origin.

Independent of the origin, playing cards became very popular in a short period of time and many different games and decks have emerged since. The early Tarot and the well spread four-suit European pack have inspired different types of playing cards in the late 20th Century, mixing strategic gameplay with collecting activity: Trading Card Games. Trading Cards appeared a century earlier as cigarette's cards and baseball cards.

The cigarette's cards were used to protect the package's content, avoiding cigarettes to be smashed (Daniels, 2003 as cited by Lenarcic & James, 2005). Later on, these cards received lithograph images and information about many subjects. The success of such cards led other companies than tobacco to put Trading Cards within their products.

The World War II and its consequent lack of paper has stopped the culture of trading cards temporary and ended the cigarettes cards for good. Sometime later, however, the trading cards went back as Tea Cards and Chewing Gun Cards. Until then, trading cards were just trading cards. By adding game rules to them, the Trading Card Games were created. *Magic: The Gathering*[12] is considered the conceptual father of all Trading Card Games (Lenarcic & James, 2005, David-Marshall, Van Dreunen, & Wang, 2010) that later in history started to be used as video game interfaces as well.

3.2.2. Card Games Analysis

For the purposes of this work, four *Trading Card Games* (TCG) were analyzed: two physical and two virtual. The games were chosen based on their popularity and importance in the market (David-Marshall, Van Dreunen, & Wang, 2010) from western and eastern cultures. Additionally, three trading card-based video game's interfaces were studied in order to understand its relationship with the physical card games on which they are based on. The

[12] © Wizards of the Coast, www.wizards.com

analysis results helped to determine the basic gameplay and graphic design of the interfaces here proposed. The digital versions of TCG were also studied and card-based interfaces in video games as well.

The first game analyzed was *Magic: The Gathering*. Created by Peter Atkinson and Richard Garfield in 1992 and published by Wizards of the Coast Inc. In 1993, *Magic: The Gathering* or just M:TG, had a first print of around ten million cards sold out in six weeks (Joseph, 1998 as cited by Lenarcic & James, 2005). Such success inspired other companies to design their own Trading Card Game around the world.



Figure 6 Magic: The Gathering Cards

Differently from M:TG, *Yu-Gi-Oh*[13] is an example of media mix product similar to other Japanese famous card games as *Pokémon*[14] and *Digimon*[15] (Mizuko, 2003). Originated from the *anime* (animation) and *manga* (comic book) of the same name in Japan and published by *Konami*, *Yu-Gi-Oh* represents a meta-language of what happens in the story of its own animation and comic book.



Figure 7 Yu-Gi-Oh Cards

[13] © Konami Digital Entertainment, www.konami.jp
[14] © Nintendo, www.nintendo.com
[15] © Bandai Company Ltd., www.bandai.co.jp

In 2001, every student in the third grade of elementary school owned a Yu-Gi-Oh card in Japan, overpassing *Pokémon* Trading Card Game (Asahi Shinbun, 2001 as cited by Mizuko, 2003) and Magic: The Gathering, which remained the top-selling until 2008 (David-Marshall, Van Dreunen, & Wang, 2010).

Following the path of many other media, the Trading Card Games were inserted into the virtual world, especially on the Internet. The number of online card games is beyond count; many of them are available in social network services and mobile devices as well. Even *Magic: The Gathering* and *Yu-Gi-Oh* have their virtual versions. Some of these games were analyzed too, for the final proposition in this section is not a physical interface.

In the *simulacra*, TCG are very different. The technology allowed those games to show more than what is in the cards. With graphical assets, 2D or 3D and even with Augmented Reality, the new Trading Card Games are more visual appealing, full of animation and visual effects.

To avoid repeat the same games already mentioned, virtual-originated games were chosen. The first game observed was *Hearthstone: Heroes of Warcraft*, developed and published by Blizzard Entertainment and based on the famous game series *Warcraft*. The game was still in beta version by time of writing, but its functionalities and card designs could be analyzed completely.



Figure 8 Hearthstone: Heroes of Warcraft Cards

One of the games from which *Hearthstone* is originated is *World of Warcraft*. It is still the top subscription-based Massively Multiplayer Online Game on market, despite dropping its numbers from 12 to 7.6 million players in the past years (Pereira, 2013). Also, Hearthstone is listed as number one of Forbes' Best Digital Card Games of 2013, followed by the online version of

Magic: The Gathering and the second digital Card Game used in this research: Ubisoft's *Might & Magic: Duel of Champions* (Tack, 2013). Also based on a successful predecessor game series, *Duel of Champions* brings the universe of *Heroes of Might and Magic* to a Card Game system.



Figure 9 Might & Magic: Duel of Champions Cards

Unfortunately, just a few games had ever used cards to communicate their functions to players and receive input from them. Most of these games are from past two or three game console generations and have no glory to boast about. Still, some were good enough to be mentioned as *Lost Kingdom*[16] series, *Kingdom Hearts: Chains of Memories*[17], *Phantasy Star Online Episode III: C.A.R.D Revolution*[18] and *Baten Kaitos*[19] *I* and *II;* and more recently, spin off games of the famous *Metal Gear* series from Konami: *Metal Gear Acid I* and *II.* All these games were analyzed, but a special attention was given to *Baten Kaitos: Eternal Wings and the Lost Ocean* and *Metal Gear Acid*.



Figure 10 Baten Kaitos: Eternal Wings and the Lost Ocean Cards

Baten Kaitos' cards, also called *Magnus*, are very simple in design, containing just the most critical information. Each card shows an

[16] © From Software, Activision
[17] © Square Enix, www.square-enix.com
[18] © Sega, www.sega.com
[19] © Bandai Namco Entertainment, bandainamcoent.co.jp

image (item, equipment, spell, etc.) and a set of numbers. The numbers can be combined to make special attacks.

Two battle mechanics were found in the analyzed games: *real-time battle system* and *strategic turn-based tactics*. In the case of *Baten Kaitos* series, the strategic element is not present leaving just the turn-based battle system, although it was found some strategic implications in the card system. In the other hand, *Lost Kingdom* games have real-time gameplay, i.e. the character can move around make actions while the fight takes place giving more freedom to the player. In the game *Phantasy Star Online Episode III: C.A.R.D Revolution* gameplay relies in a complex strategic combat involving many characters at same time. *Metal Gear Acid* series follows this same pattern and even the character movements are card-controlled.



Figure 11 Metal Gear Acid Cards

The observed games have many of the printed trading cards elements including customizable decks, card's attributes and illustrations. The card's design and layout follows the game design guideline as expected but they all share elements, mostly because of its common origin. These elements include values for using cost, attack and defense and additional effects upon use. Some cards contain a brief text description of its effects and a *flavor* text that do not interfere in the gameplay. All cards bear some artwork to better illustrate what the card represents. Similar to the printed card games, virtual ones may also be divided by type such as *creature* or *character*, *artifact, ability, weapon, etc.,* and by color or element as *fire, water, wood, earth* and so on.

The reviewed cards' characteristics were summarized as *artwork, category or type color, mechanics, indicative numbers* and *information area*.

As a result, *Trading Card Games*' features were aligned to matching ARCS-REACT heuristics, facilitating the further design and development:

Table 4 ARCS-REACT Cards Analysis

ARCS-REACT	CARD GAME FEATURES
Attention	Artwork, Card Color
Relevance	Information Area
Confidence	Indicative Numbers, Cards Mechanics
Satisfaction	Combinations for special attacks/items
Relating	Common elements between card-games
Experiencing	Clear Information, Simple Mechanics
Applying	Challenging Mechanics
Cooperating / Transferring	Tradable cards;

The presented set of features were applied in the prototype design but not before user's tests, explained in the next topic. Moreover, the studied video games' mechanics with card-based interfaces were distributed into three categories: *free, turn-based* and *strategic*. These categories will be used later in the decision making process to define the prototype core mechanics.

3.2.3. User Tests

Before apply the card-game based interface in the prototype development, a user playability test was conducted. The experiment aimed to evaluate whether the card-based interface is more effective than the usual buttons interfaces regarding player's experience and game mechanics interaction. To perform this analysis a true experimental research design with pretest-posttest method was used.

So as to attend this question, a simple method involving design needs and requirements (Hartson & Pyla, 2012) was applied in the card development and heuristic evaluation (Nielsen & Molich, 1990; Rogers, Sharp, & Preece, 2011) for the prototyping process. Same ARCS-REACT approach was used in order to create a better experience and observe the method in the first experiment prototype. Thus, a background story and simple game mechanics was created to deliver an immersive experience to the user

during the tests. The prototyping workflow described in last section was also used and tested in preparation for the final version development.

If something Playing Cards are complex information holders full of signs and playful content. In that sense, a user-centered approach based on cognitive and communicative aspect of interaction (McKay, 2013) was used to fulfill the product requirements in combination with a community-centered design approach (Preece, 2000).

Trading Card Games are very social activities. Video games in general are becoming more social nowadays. As discussed above, MMOG can be turned into a great tool for CTL just because its social features. Considering all these social factors, a community-centered design approach was really useful. Furthermore, it helped to define the target audience. By choosing a community in the first place, its users naturally composed the test group that the interface was designed towards.

Following that direction, two Brazilian communities with common interest were chosen. They are organized in the Social Network Service *Facebook* under the names *Nerd Power* and *SkyNerd* with 3.660 and 1157 users respectively in the time of writing.

The communities were chosen not only for its size, but also for the social learning element found in it. As the names suggests, they share common interest on *nerd* content, what varies from pop culture to quantum physics. The nerd community around the world has been bound to a negative stereotype for a long time (Kendall, 2001), but the past two decades the nerds and geeks, or the *Third Culture* (Kelly, 1998), has become popular and important to the media and industry.

Nerd communities usually share and discuss their subjects with great enthusiasm. It carries many constructivist elements associated with some relevant content, what promotes CTL. The communities here observed use a variety of media to share and discuss content, including podcasts and *video logs*.

As mentioned, a game prototype was developed in a community-centered design. It was a Massively Multiplayer Online Game with a narrative coming from many distinct community's resources. A video game needs an

interface as any other tool, and in this particular case, the Trading Card Game proposition was applied and evaluated.

The game prototype called *SkyNerd Protocol* is set in a post-apocalyptical Earth, when natural resources are scarce and knowledge of the human race of late is lost but for some artifacts to found during the game progress, artifacts that represent human History, Science and Art. The game's context is also well placed over environmental issues, as climate changes and preservation of natural resources. On top of all that, social, politic and economic discussions are contextualized in a world that has suffered with war and must now survive an atomic winter.

The context the game is based on can give room to many and contextual learning. For the proposed experiment, a simple game mechanics was designed following the *real-time battle system* observed in some games earlier during the research. The game's goal is to find five hidden chests in which famous original paintings are stored. To open each chest, the player needed a card corresponding to the painting artist. A deck of 10 cards was created (Figure 12) and 4 cards were drawn each time for the player to choose.



Figure 12 Card Deck of Famous Artists

Each card holds information about the artists as year of birth and death (if applicable), brief bio and a quote, designed accordingly with the Card

Games previously analyzed. Because the target audience is Brazilian, the information is written in Portuguese. Following the community-based approach, the cards were designed based on comic books, a common media among the target community. This Card-based User Interface will be henceforth referred as *High Contextual UI* (Figure 13).

The second interface was based on traditional MMOG, such as *World of Warcraft* and *Star Wars: The Old Republic*. Those games make use of common icons to represent character abilities or items and labels which bear the necessary information to be viewed when the user roll the mouse over it. This Button-based User Interface will be described here as *Low Contextual UI* (Figure 14).



Figure 13 High Contextual UI



Figure 14 Low Contextual UI

Once again, the interface comes with the artists shown in the Figure 13 and the info only appears in the mouse over state of the icon. The button or icon-based interface does not require the same gameplay as the Trading Cards; therefore, all icons are visible and available for the user all the time. Once inside the game, the users had to answer 5 questions about Art History regarding the paintings and artists in the game. After completing the game, users were prompted with the same questionnaire again. The difference between the answers have given some directions on which interface is better for CTL and if the learning process is in fact occurring.

The game prototype was tested with 20 volunteers from the mentioned communities, 17 males, 18 students, all Brazilian from 10 different cities and 9 states during the period between 7 and 9 of January of 2014. The users installed the game software, available for Windows[20], Mac OS[21] and Linux[22].

The prototype was programmed to run just once and guide the user through the first set of questions about Art History just after filling a form with personal data. To the user was given plenty of time to explore the simulated environment and find 5 pieces of lost famous paintings. Half the players used the Trading Card Interface and the other half the common MMOG abilities' icons. At the end of the game, the users were prompted with the same questions already answered but with a new question in place of the last one. The educational level of the players can be seen in the following graphic:

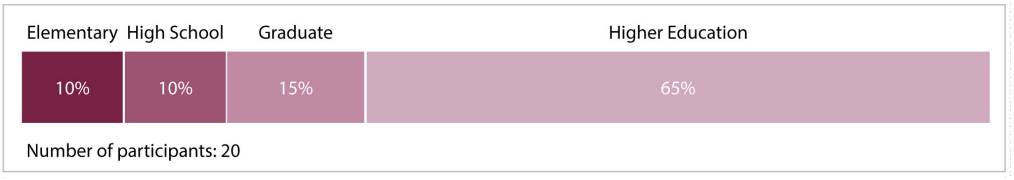


Figure 15 Participants Education

[20] © Microsoft Corporation, www.microsoft.com
[21] © Apple Inc., www.apple.com
[22] © Linux Mark Institute, www.linuxfoundation.org

Also, the level of gaming experience was questioned (Figure 15) with most of participants stated as regular or advanced players. Just 5% have said they're beginners. It was important to establish whether the game mechanics or the interface complexity could interfere in the final results. Despite of a well balanced distribution, 80% of the players affirmed to play more than two hours per week, 60% more than 5 hours. It was considered enough for the simple game mechanics presented and to follow the interface instructions. The game playtime feedback (Figure 16) also provided at the end of the test showed that 70% of the players could finish the game in less than 3 minutes or close enough, what maybe points to a fast game's learning curve, clearly attenuated by the users' previous experiences demonstrated in the following chart:

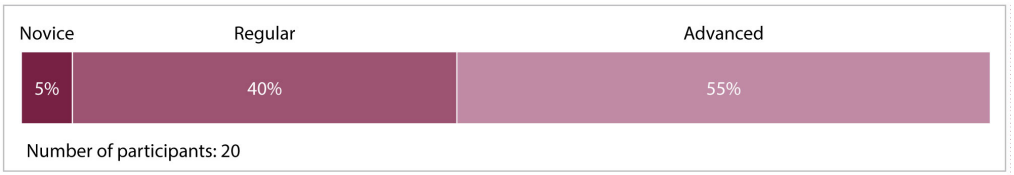


Figure 16 Participants Game Experience

With the data collected, the analysis was performed. To address the main problem pointed in the beginning of this section, three research questions were formulated. The first question says:

- *Can High Contextual User Interfaces help players to complete a game quickly?*

The first assumption was related to the time and stated that players using buttons UI, i.e. *Low Contextual UI*, would take longer to complete the game prototype as the null hypothesis bellow:

- *H_o1: High Contextual UI players will take a longer time to complete the prototype than Low Contextual UI players.*

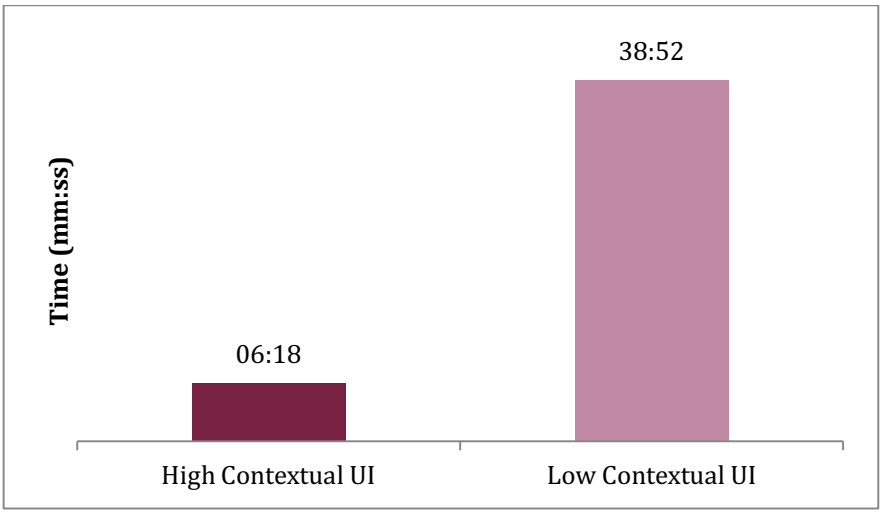


Figure 17 Total Playtime

Based on the given playtime averages, it is possible to conclude that $H_o1: \mu > 38:52$ is false, hence, is possible to conclude that contextual interfaces facilitates the game mechanics as to complete the game objectives quickly.

Secondly, subjects' performance was measured and compared in two different tests. A pretest-posttest comparison and a game score analysis. The pretest-posttest method was intended to answer the second research question:

- *Does High Contextual User Interfaces affect players learning process?*

To achieve the solution to the stated question, the following null hypotheses were taken:

- *H_o2: High Contextual UI players will score less than the Low Contextual UI players in the posttest.*
- *H_o3: High Contextual UI players will show lower improvement than the Low Contextual players.*

The mean test score for High Contextual UI players was 2.5 and 3.2 for before and after respectively. The same result for *Low Contextual UI*

users was 1.9 and 2.9. Since H_o2: $\mu > 3.2$ is false, the *High Contextual UI* players have had a better performance. However, after analyzing the given data it was possible to see that H_o3 is true, for *High Contextual UI* players showed a 0.7 mean of improvement, i.e. the difference between the first and second test, against 1 from the *Low Contextual UI* as seen in the chart bellow:

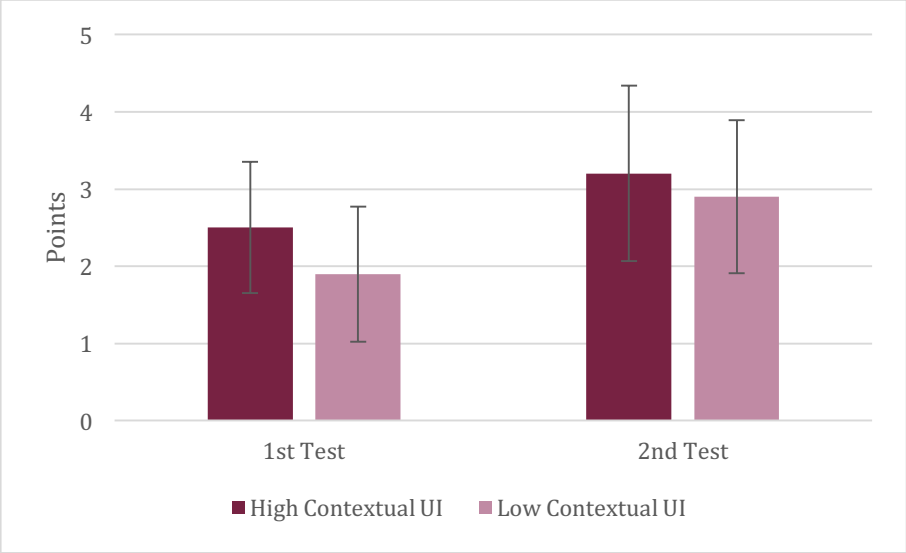


Figure 18 Pretest and Posttest Score

A T-Test with two sample assuming unequal variances returned a *P-Value of 0.2*, rejecting the null hypotheses. Therefore, it is possible to conclude that *High Contextual UI* helped players to achieve higher scores but *Low Contextual UI* had a greater impact in the knowledge building process of the subjects.

Regarding the game total score, represented by the number of times a player successfully opened a treasure chest minus the number of times the player's answer was incorrect, a third research question was inquired:

- *Can High Contextual Game Interfaces help players achieve higher scores in the game?*

As to answer this question, the following null hypothesis was tested:

- *H_o4: High Contextual UI players will score less than the Low Contextual players in the game prototype.*

The graphic in the next figure demonstrates a better performance for users using the Contextual UI. For each correct button or card used, 100 points were given to the player. Each wrong choice resulted in minus 50 points in the game.

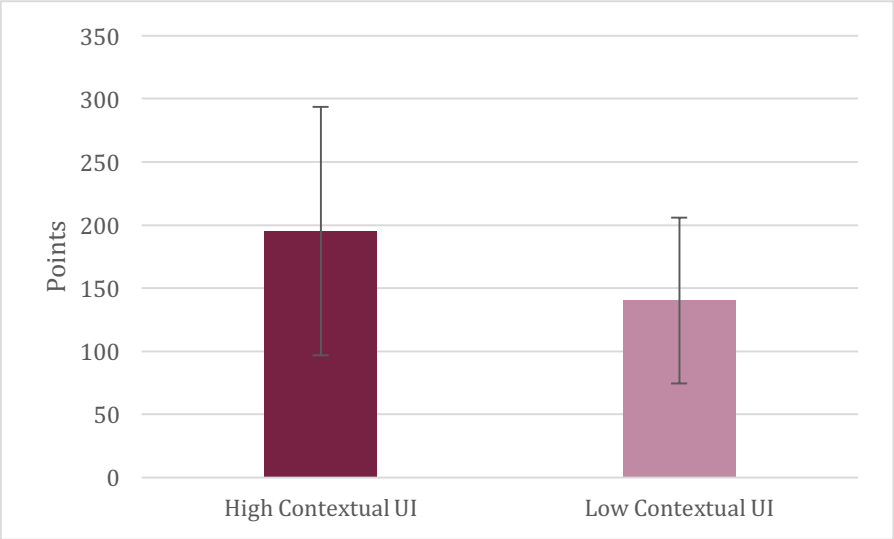


Figure 19 Game Score

The average score for the *High Contextual UI* group was 195 points against 140 for Low Contextual UI group. Since *H_o4: $\mu < 140$* and the T-Test with two sample assuming unequal variances returned a *P-Value of 0.05*, the null hypothesis was refused and the *Contextual User Interfaces* therefore have facilitated players towards a best game score in average.

3.2.4. Results and Discussions

Based on the previous study, we can answer whether the card-based interfaces are more effective than the usual buttons interfaces regarding player's experience and game mechanics interaction with some discussions. The following table summarizes the research questions and hypotheses:

Table 5 Contextual UI Hypotheses Summary

HYPOTHESIS	TRUE
Low Contextual UI players will take a longer time to complete the prototype than High Contextual UI players.	O
Low Contextual UI players will score less than the High Contextual UI players in the posttest.	O
High Contextual UI players will show lower improvement than the Low Contextual players.	X
Low Contextual UI players will score less than the Contextual players in the game prototype.	O

Based on these findings, the following list of conclusions can be then elaborated:

- High Contextual Interfaces facilitates the game mechanics as to complete the game objectives quickly;
- High Contextual UI helped players to achieve higher scores in the posttest;
- Low Contextual UI had a great impact in the knowledge building process;
- High Contextual User Interfaces facilitates the best game scores in average.

Cards can carry more information visible to the player in real-time while buttons usually show only icons and numbers, with the need of a mouse-over to access the details. Consequently, the understanding of the game mechanics was probably more accurate with the High Contextual UI group. This understanding could have promoted the completion of game tasks in a considerably short time.

Regarding the pretest-posttest method, this study assumes that the lower improvement in the posttest scores for the High Contextual UI players does not imply in a better performance for the other group. The interpretation here is that as the High Contextual UI group had a better performance in the pretest, consequently, the room for improvement was narrower than the Low Contextual UI group. Hence we cannot say if the Buttons UI really had a great

impact on learning process. The recommendation is that a posttest-only research can clarify this issue in future works.

Finally, the game score analysis showed that High Contextual Interfaces had a great impact on game score. This is likely to be related to the how such kind of UI can bear more and clearer information than buttons, facilitating the comprehension of the game mechanics and goals, thus promoting a good player experience and smoother playability. That's the reason the Card-based UI was referred as High Contextual in this study.

The results here presented are just the first step towards a complete interface proposition. As conclusion High Contextual UI has promoted a better, faster and intuitive gameplay what resulted in greater game scores and information absorption. Button UI proved to be less clear and complicated to use, even though it is the most common interface in MMOG and most players were advanced game users. These findings will be used in further sections in the final prototype design, development and testing.

3.3. Character Design

One of the most challenging tasks found in this work was the character design and definition in accordance with the ARCS-REACT model proposed. In order to achieve a character with whom the player could create a close relationship and thus feel stimulated to play and replay the game, a brief study was needed. A comparative method was applied with three Massive Multiplayer Online (MMO) games and cultural aspects of Brazil's players, certainly involved in human interaction with an educational system.

To guide the design process of character development, some avatar creation and customization systems were analyzed. It is an important part of MMO games and defines a relevant aspect of user interaction with the game world: the avatar itself. The objective of this section is to establish the starting parameters for the avatar's creation following the parameters defined in the ARCS-REACT model respecting ethnics aspects of the target audience for the user tests.

The results obtained through an exploratory and a comparative method applied between three Massively Multiplayer Online Games has

indicated seven Brazilian ethnic groups to be used as the basis of character conception and important properties to be used in the design needs and parameters method applied later in the prototype development.

3.3.1. Avatar Creation and Customization

Before going through the main goal of this segment is necessary to set up some essential concepts. First of all, the MMOG itself, as one of the most popular genre of games nowadays. The terms MMOG is commonly used to describe a subgenre of games that allows the user to play over the Internet with hundreds or thousands of other players (Darby, 2011). The acronym MMOG means Massively Multiplayer Online Game. The reason such kind of game was chosen in this comparative analysis is that MMOGs have a great tool for users to customize their own characters. Additionally, the ability to play the game and interact with other players makes this kind of digital world one of the best environments to promote education according to theories of cognitive interaction involving participation in a community in order to construct the knowledge (Steinkuehler, 2004). Also, this same community is responsible in the process of culture generation through nature. The character or avatar is an important component in this complex process.

The virtual representation of conscious beings in synthetic environments, immersive and ubiquitous, is the so-called avatar (Coleman, 2011). The Hindu idea of a god among people through a physical manifestation is the origin of the word avatar and the concept behind this virtualization process.

The actions performed behind the avatar's mask reflects a new way to communicate, but also it is related to how people act differently behind different avatars. It gives freedom somehow to people enabling not only to "be" someone else but also to act as someone else. These aspects imply an interpolation of culture, of what the individual takes to the virtual environment and what he will get from there and more important: the sum of all those experiences.

For consider this process of creation culturally important and because it is the first challenge the user faces inside the MMOG when entering

for the very first time, this work aims to discuss more about how to develop a system for distance learning that allows the student to create and customize his own character.

Character creation usually begins with choosing race and genre. It will reflect in the character's background, its species, physiognomy, history, heritage, philosophy and so forth (Kelly 2, 2004). The second feature to be chosen is the appearance. MMOG offers a wide set of visual configurations, from facial characteristics to body shapes. It involves variations in morphology of the character race and external modifications as make-ups and props as well. The third step on character creation is the definition of a class. The class represents an important element in the balance of the game affecting directly in the group's gameplay, essential in a MMOG (Kelly 2, 2004).

This study has focused on the appearance aspect of avatar creation, for the prototype's character genre will be both male and female and the race will be human. The purpose is to create a link between the player and character. It will be possible, probably, in the future to change the appearance of the avatar in a variety of ways, but in this first moment, only one race will suffice for the research purposes.

Also, the time to develop the prototype was limited, therefore, the development of a complex system of player classes is off table right now. The only class present in the prototype will be mage or wizard, for it represents an iconic and common class in a great number of MMOG and because magic effects are visually appealing, one of the requirements of *attention* category in the ARCS-REACT model used here.

Three different MMOG were analyzed in order to study the customization mechanics and appearance features. The basis to decide which MMOG should be included was the design style direction (Mastri, 2006). According to the author, character styles can follow two different designs: realistic and stylized. The realistic approach seeks a more detailed character while the stylized represents a more cartoonish visual.

Following this line of thought, the selected MMOG should represent each one of Maestri's character design categories plus a third game which fits in-between the mentioned styles. The Figure 20 shows the three selected MMOG characters, from the most realistic (left) to the most stylized

(right): *Start Wars: The Old Republic*[23], *World of Warcraft*[24] and *Ragnarok Online II*[25].



Figure 20 Character Design Styles

Ragnarok characters show a more stylized visual while *Star Wars* is directed to a more realistic graphic. *World of Warcraft* visual style was considered the middle point between these two games.

Star Wars: The Old Republic is based on the world-famous *Star Wars* franchise. Released in 2011, the game gives the player possibility to explore planets and fight for the *Republic* or the *Empire*. The game now counts with over 1 million active players after a sudden decline just after its release, forcing the business to a free-to-play model (Gera, 2014). *World of Warcraft* is considered one of the most successful MMOG of all times. After reaching a peak of over 12 million subscribers in 2010 (Irvine, 2010) the game numbers have declined progressively since then, but after the last game expansion, *Warlords of Draenor*, jumped again from 6.8 million to 10 million active subscribers (Grubb, 2015). Based on the fantasy manga written by *Myung-Jin Lee*, *Ragnarok Online II* is the 3D, 2013 sequel of homonymous 2D isometric game from 2002 (IGN, 2013). It's a fantasy free-to-play MMOG developed by Gravity Communication and published by AsiaSoft.

3.3.2. Appearance Aspects

Among the concepts explored so far, the avatar's appearance is most complex to understand and apply in an interactive system. The reason is

[23] © LucasArts, BioWare, Eletronic Arts, www.starwarstheoldrepublic.com
[24] © Blizzard Entertainment Inc., www.blizzard.com
[25] © Gravity Communication, AsiaSoft, www.asiasoftsea.com

related to the psychological and sociological aspects involved. One of these aspects relays in the body and conscious' relationship and how in the postmodern times this connection is not only restricted to a physical body (Le Breton, 2008). The following table summarizes the avatar's options for each game:

Table 6 MMOG Avatar Customization Features

STAR WARS: TOR	WORLD OF WARCRAFT	RAGNAROK ONLINE II
• Body Type • Head • Scars • Complexion • Eye Color • Patterns and Cosmetics • Headbands • Skin Color	• Skin Color • Face • Hair Style • Hair Color • Piercings	• Hair Style • Hair Color • Face Style • Eye Color • Eye Style • Voice

To relate the summarized characteristics with the target audience, four distinct ethnic groups in Brazil from many different origin and mixtures, as show in the following table were studied:

Table 7 Ethnics Groups in Brazil

GROUP	DESCRIPTION
White	The major part of this population are European decedents, mainly from Portuguese, Spanish, French, Italian, Dutch and Slavic. Most of them lives in the south region of Brazil.
Black	Were forced to work in Brazil as slaves in a past time in the sugar and coffee production. After the end of slavery, they are still concentrated in areas where the work exploration were more intensive, as northeast and southeast regions.
Indian	The native population before the Portuguese colonization. They were almost totally exterminated during the colony period. Actually they live mainly in north and central region of Brazil.
Brown	Originated from the miscegenation between White, Black and Indian.

Also, three sub-groups of the Brown above as shown in the next table:

Table 8 Ethnics Groups in Brazil

GROUP	DESCRIPTION
Mulato	Comes from the union between White and Black. They represents 24% percent of Brazilian population and lives mostly in northeast and southeast regions.
Caboclo	Descends from the mixture between White and Indian groups. They represent 16% of Brazilians and lives mainly in the north and central regions.
Cafuzo	The minority group represents only 3% of population. Comes from the miscegenation between Black and Indian and lives mainly on Amazon, northeast and central regions.

Most of characteristics found in the analyzed MMOGs more related to ethnicity than culture, but both concepts are directly and strictly linked and have an important area of interpolation where the individual's subject exist. Not only eyes, nose and mouth are ethnicity studies dependent but more important: the skin shade.

In the case of Brazilian students, it is more difficult to establish customization parameters based on the ethnicity and culture because of the country's size and history. It was found very difficult to establish some criteria on how to classify human visual characteristics through the complicated Brazilian categories based on skin shade for it does not reflect the common black-white paradigm (Chang & Dodd, 2001).

Those groups were formed along the History through the combination of five original groups: Natives, Portuguese Colonizers, African Slaves, European Immigrants, Asia and Middle-East Immigrants. Based on this, there is still one more aspect to consider in order to develop a Brazilian based game character: the immigrants. There are, for instance, a considerable number of Japanese immigrants in Brazil.

Started in 1908 with the *Kasato Maru* steamboat arriving at Santos Port, the Japanese migration to Brazil represents an important aspect of Brazilian development and culture, especially in the southeast and Amazon regions (Masao, 2008). Considering that and the fact that today there are many children of Japanese immigrants and other cultures as well, it is possible to

assume a student player should be frustrated for not be able to find their own ethnic characteristics in the system.

3.3.3. Conclusions

The MMOG avatar features found in the three analyzed games were combined with the seven Brazilian ethnic groups found and main immigrant's descendants to help in the definition of a character design direction for the prototype development. The main characteristics of each group was turned into archetypes for a starting point of creation.

First point attended was the character style direction. According to Maestri (2006), stylized characters are more appealing to the public. Also, the author states that people expect realistic characters to act realistically. In that sense, animation and environment should also be executed realistically, i.e. closer to the physical world. This extra difficulty could hinder the prototype development and compromise the research user tests. Likewise, as proposed in the ARCS-REACT model, the more appealing visual style is preferred to promote *attention*. Thus, the more stylized design was chosen to direct the characters' creation.

The possible options taken in consideration for the character creation were skin color, hair style, hair, color, eye style, eye color, face and clothes. The design followed the *anime* style art and colorful costumes. The mix of ethnics' characteristics with the followed design style has resulted in the set of characters show in the next section (figure 21).

3.4. Matemagos

The final prototype, a *Web Browser* game called *Matemagos*[26] was developed based on the prior experiments and theoretical framework. In this section the most important aspects of the prototype design and features will be explained. *Matemagos* game was used to apply the user's tests in order to answer the main investigative question of this research.

[26] From two Portuguese words that can be translated as *Mathmages*

3.4.1. Game Overview

Matemagos is an arena battle game with a turn-based combat system based on *Japanese Role Playing Games* (JRPG). The player must choose four characters between six elemental available mages, each with specific abilities to defeat elemental enemies in arena-shaped scenarios.

The Figure 21 shows the available mages and their elements in the art of Brazilian illustrator Emanuel Braga. From left to right: arcane, earth, fire, water, wind and nature. The variety of elements offers a good strategic feature, but it is in the interface that Mathematics is put into use.



Figure 21 Matemagos

Following the Trading Card-based user interface chosen to compose the command input system, four cards representing each chosen mage's element are drawn in each turn. Every single card carries a number and between the cards there are basic arithmetic operation symbols. In order to use the card's power, the operation must be solved in any combination of cards. The final prototype was used in user tests with Brazilian students. The

experiment's results can show the game's effectiveness and also help to improve it in the future.

3.4.2. Design Method

The development method implied design needs and requirements (Hartson & Pyla, 2012) and followed the provided heuristics in the ARCS-REACT model seen in section 3.5 (table 3), three important design elements were defined as needs: story, graphics and gameplay. Story is also important in the sense of CTL and experiential theory, for it represents the contextual universe in which the students will interact and therefore, construct meaning and knowledge. The design process took two distinct needs and requirements tables: one technical and one conceptual, based on the ARCS-REACT categories. The technical parameters are described as follows:

Table 9 Technical Design Needs and Requirements

NEED	REQUIREMENT
Run on basic computers	Low-poly models; low-res textures; mono audio; efficient code.
Good graphics and sound quality	Anti-aliasing; multi-resolution models; multi-resolution textures; audio streaming; preloading.
Multiplatform	Build for Android, iOS and HTML5
Low cost	Use free or low cost tools
Store data online	MySQL server and PHP connection

Some requirements represented a challenging achievement, for instance, find the balance between good graphics and sound quality in a game capable of run on Web Browsers and portable devices of basic settings. Regarding the ARCS-REACT requirements, the following table 9 shows what guidelines were pursued.

As seen on the table, some additional development was required. The game server was hosted in a private hosting under the domain

www.matemagos.com. The website provided users with game information about gameplay and game story alongside with player scores and research goals explanations.

In order to make the game communicates with the website and send data to the game server, a MySQL database was set. Communications between prototype and game server was done via PHP.

Table 10 ARCS-REACT Needs and Requirements

NEED	REQUIREMENT
Attention	• Particle Systems; • Sound Effects; • Fixed camera; • Camera animations; • Game story background;
Relevance	• Game instructions onscreen and on game website; • Charismatic characters; • Immersive 3D scenario;
Confidence	• Player's control on sounds level; • Game score onscreen and on game website; • Game controllable by numeric and alpha-numeric keys; • Game controllable by touchscreen; • Colors to guide player's understanding of gameplay.
Satisfaction	• Short battles. • Challenging battles; • Players' performance and score announcements after battles;
Relating	• Game based on JRPG; • Clean User Interface. • Integrated gameplay tutorial.
Experiencing	• Easy to understand interface and icons; • Camera animations to show off characters before battle; • Dramatic endings for win or loose situations;
Applying	• Game difficulty level rises progressively; • Game difficulty level set accordingly to players skills;
Cooperating	• Game connection with game's website; • Online Game Score;
Transferring	• Game website with communication tools; • Game page on Facebook.

3.4.3. Graphics and Visual Effects

Graphics represents a challenge in multiplatform games. It must fulfill the quality requirements and also, run on all target platforms. Graphics are related to a better user experience and game enjoyment (Zhao & Fang, 2009). It's an important factor to promote the game attractiveness. 3D models for characters and environment were created. Although they are low poly models to run on mobile devices, special attention to the textures was paid in order to keep the design as attractive as possible.

The graphic quality of commercial games was compared to educational games in order to create a parameter. A fourth need was created to promote inclusion: multiplatform, i.e. capability to run on mobile platforms (Android, iOS) and Web (HTML5), thus accessible by most of students and school's equipment.



Figure 22 Matemagos Screenshot

The proposed game prototype was developed with Unity and aimed to be lightweight enough to run on multiple platforms. Conceived with bases on the mentioned approaches, it is an arena-style, turn-based combat game with 10 levels and 6 characters based on natural elements: fire, water, wind, earth, nature and arcane. The Figure 22 demonstrates the layout of the battle system in the gameplay.

3.4.4. Game Story

Story is a very important factor in a game, it's "the difference between a good game and a great game, because the story helps to further immerse the player in the game world." (Chandler & Chandler, 2010). The story attracts player's attention, increases player's curiosity and makes a more enjoyable game (Zhao & Fang, 2009).

With that in mind, but considering that mobile screen limitations cannot afford to tell a very complex story, a game background was created: six mages from the distant realm of *Tabu'ada* unite effort to find a long lost tome: *The Book of Power of Two*. There is no need to describe the details of their adventures here, but the mages must search every corner of the realm for this great artifact.

3.4.5. Game Style

The game genre followed in this development was the *Japanese Role-Playing Game* or JRPG. This video game genre came from the traditional *Role-Playing Game* or *Tabletop RPG*, a group activity that commonly uses paper, pen, books and imagination to interpret created characters in an adventure narrated by a *dungeon master* (Finney, 2004; Fine, 2002; Tresca, 2010). According to Fine, the first RPG game was *Dungeons and Dragons*[27], created by Gary Gygax and Dave Arneson based on wargames like *Chainmail* in 1974. According to Tresca (2010), RPG creation was strongly spired by the *Trading Card Games* mentioned before in this study and used as User Interface element in the prototype.

With the advent of computers, the RPG games began to migrate to the virtual world. First, the hypertext adventure games became very popular (Slater, 2004). The so called MUD (Multi-user Dungeon) combined databases and network to allow players read stories and choose multiple non-linear paths (Tresca, 2010). Later, in 1979, the first *Computer Role-Playing Game* (CRPG) was lauched to the Apple II[28] computer: *Akalabeth: World of Doom* (Barton, 2008). It combined elements of MUD with *Dungeons and Dragons* features as

[27] © Wizards of the Coast, wizards.com
[28] Apple Inc, www.apple.com

character classes, leveling, combat strategies and exploring. Apple II computer also received the first of one of the most important CRPG series: Ultima, which was an inspiration for the Japanese Style RPGs.

The difference between Western Style RPG and JRPG is so big, Kurt Kalata (2008) suggests they seem to pertence to completely distinct game genres. According to the author, JRPG focus are more on storyline and battle system. This special distinct CRPG sub-genre had its debut in 1986 with *Dragon Quest*[29] for *Nintendo Famicom*[30] system. Based on American CRPGs *Ultima*[31] and *Wizardry*[32], Yuji Horii developed the game which would inspire great video game franchises as Final Fantasy[29] and Phantasy Star[33].



Figure 23 Final Fantasy IX Battle Scene

Japanese RPG games have incorporated many features to Computer RPGs. According to Tresca (2010), they have introduced the combination of magic items with weapon and armor enhancements and the crafting of new items. The author defines the JRPG as more complex and deeper compared to other games. As seen in the prior study demonstrated in section 3.5.1, 20% the target audience pointed JRPG as reason to choose a game to play, therefore this will be the style of the prototype.

[29] © Square Enix, www.square-enix.com
[30] © Nintendo, www.nintendo.com
[31] © Eletronic Arts, www.ea.com
[32] Sir-Tech Software
[33] © Sega www.sega.com

3.4.6. Core Mechanics

The gameplay must be simple and use Mathematics as element. Of all three core game design elements been considered here, the gameplay is the most important because it will bear all the Mathematics mechanics and also is the most directly related to the user experience through interaction. For these reasons and because it's recommended to isolate the core gameplay mechanism to avoid confusion (Fullerton, 2008), it will be described in the later.

It is not the objective of the present work to explore the details of *Matemago's* mechanics, thus the focus on this section will be the core gameplay mechanics. As a turn-based game, the mechanics of battle system is important and although is no part of the core gameplay it will be explained as well. For now the core mechanics was defined as the actions the player must repeat in order to achieve the game's overall objective (Fullerton, 2008).

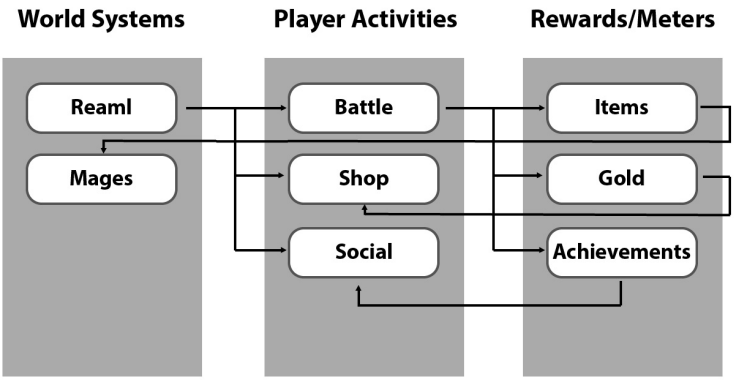


Figure 24 Core Gameplay Mechanics

According to the stablished core gameplay the player must chose four Mages from six available and in the Realm Map chose one of ten Levels in which the Battles will take place. From the Realm is also possible to access the Shop and the Social areas. The battle rewards are Items, Gold and Achievements. The Items can be used to better equip the mages for the next battles. Gold can buy equipment as well, but other than those enemies can drop. All the achievements can be shared in the Social Media area. The key gameplay concepts to achieve here are: fun, choice, reward/progress and Mathematics learning as the basic game pillar (Iuppa & Borst, 2012).

In a turn-based combat based on Japanese RPG, the player will have time to perform actions before the enemy's attack. This time is called a turn. This system was chosen to give the player time to solve the Mathematics operations provided during the battle. In the combat system, two basic concepts were used in combination: nature elements and numbers. As mentioned before, each Mage represents one element and has a corresponding card (Figure 25). In each turn of battle four cards representing one of each Mage's elements are draw randomly.

The cards also bear a number and between cards there are operation signs. To perform a successful attack, the player must solve the basic operation. If the whole operation is to difficult for the player, only part of it can be solved. Any combination is possible, but the resulting attack will be less effective. Using the Figure 22 as an example, the whole operation is 7+8×4+3. If 42 is answered, all the card's elements will be combined and make much more damage. But if 15 is the answer, i.e. the solution for the first two cards, the spell will be weaker, still inflicting damage. The player can answer using the numeric buttons on each side of the display, positioned for easy access with player's thumbs on a mobile screen. For each wrong answer, the enemy performs an attack.



Figure 25 Cards and Elements

The algorithm to randomly generates the Mathematics operations was developed based on *The ArithmAttack*[34] open code from the *U.S. Department of Energy's Argonne National Laboratory*. It takes in consideration a difficulty level variable yet to be improved. Besides the Mathematics operations, when the player combines cards, the elements are also mixed to create spells. If fire and earth are combined, for instance, a magma spell is cast the same way water and wind will create a blizzard, two fires an explosive fireball and so on. These combinations can aggregate one extra layer of strategy to the gameplay.

3.4.7. Game User Interface

As the User Interface is a key element in the gameplay, specially for this prototype, since its card system is directly related to the character actions in-game, some its aspects were already covered in the last section. Nevertheless, it is worth explore a little bit more about each one of the GUI elements.

First of all, the game start screen (figure 26) was designed to be simple and yet attractive for the target audience, 7th grade students. The interface shows an animated background, the game logo and two input fields for user name and ID. There was an option to remember player's name, start button and sound configuration button.

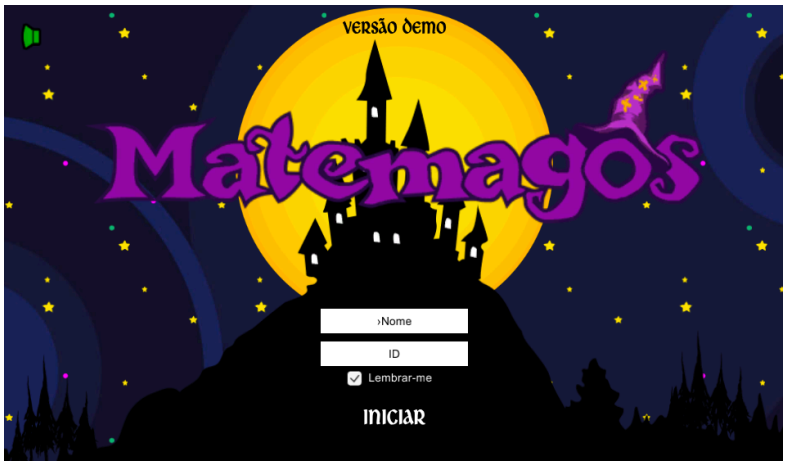


Figure 26 Matemagos' Start Screen

[34] http://www.math.com/students/practice/arithmattack.htm

The Figure 22 in section 4.3.3 shows the battle screen and the next image shows its layout in details. The light-blue buttons are touchscreen-only and thus did not appear when in WebGL HTML5 version of the game. All the UI elements were developed to fit different screen resolutions and sizes.

There are three critical elements in the battle screen HUD: cards, signs and time bar. All these key elements were positioned in the bottom portion of the screen, centralized. The cards, also called *Magicards* were designed following the previous study over *Trading Cards Games* and *Card-based Game User Interfaces*. Its layout was arranged to be as simple as possible and comprehends an elemental image as seen in Figure 22 and a center-aligned number. Between the cards there's the arithmetic operation signs +, -, x and ÷. The last card corresponds to the answer and starts with a question mark (?). The answer card does not contain an elemental image on it and starts yellow-colored, turning green if the player's answer is correct or red if the player's answer is incorrect.

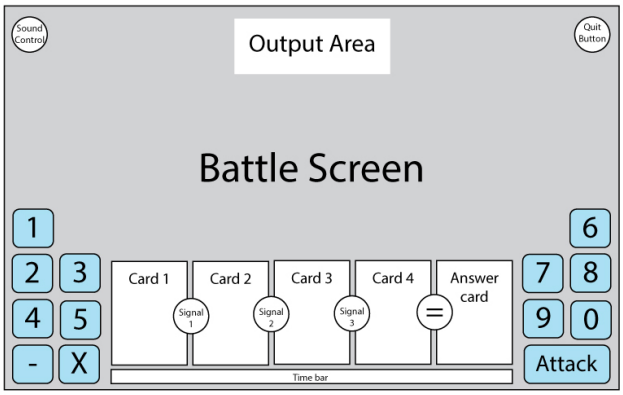


Figure 27 Battle Screen Layout

The players input, i.e. the inserted numbers, is showed at the top of the screen in the center and can be changes as long as the time bar is not empty. Cards and signs are randomly sorted at each battle turn and enter and exit the screen area with an animation. A battle turn lasts 12 seconds or until the user press enter/return on the keyboard or the attack button on touchscreen devices. The time remaining is displayed by the time bar, which starts green-colored and full, turning gradually red as the and empty as the time counts

down. Timer bar also enters and exit the screen area with an animation and fill up again on every beginning of battle turn.

To provide the player with feedback in-game, some UI elements were positioned in the 3D game space. Over the hear of each character there's a bar representing the character's health. Similarly to the time bar, the health bar starts green and becomes red as the character's life diminishes. Additionally, on every attack or heal, an animated number appears over the character's head representing the amount of damage (red number) or heal (green number).

The feedback for the end of the battle was provided by two screens: Victory and Game Over. The Victory Screen (figure 28) shows the player's score (percentage of correct answers) and the buttons to play again and quit the game.



Figure 28 Victory Screen



Figure 29 Game Over Screen

The next figure (Figure 29) shows the Game Over Screen. Similarly to the Victory Screen, the Game Over shows the buttons to play again and quit the game. It was designed to be a little dramatic, showing a spotlight over the dead mages.

The drama was intended to create a closer relationship between the player and the characters. The feeling of loss could stimulate players to play again. Same effect was intended with the Victory Screen, with a panoramic view of the mages and a fanfare sound to encourage users to play one more time.

3.4.8. Game Camera

This game uses a 3rd person camera style (Finney, 2004), i.e., the user can see the characters from above. As following the classic JRPG style games, during the battle, the camera is fixed and the player cannot control it. The fixed camera style was chosen because the player's attention should be totally in the Mathematics operation displayed in cards.

The battle arena layout is configured in a way that all characters are visible all the time. At the beginning of the battle the game camera performs a panoramic view of the scenario, but just before the cards are sorted, the camera takes the best position for user visualization of all game elements. If the correct answer cards contain the same element, the camera then performs a close up view of the correspondent mage.



Figure 30 Game Camera Close Up

The camera animations and the particle effects seen in the figure above were considered important to attend to *attention* heuristics present on the design needs and requirement table. It provided a dynamic visualization of the scenario and characters, contributing with the game's immersion factor and player's involvement with the gameplay and characters.

3.4.9. Sounds and Haptic Feedback

The same aspects of the ARCS-REACT model used to the visual part of the game were considered in sense of sound. Open-source sounds[35] were mixed and used following some directions:

Table 11 Game Sound Features

GAME SECTION	SOUND FEATURE
Start Screen	Relaxing, Sparkling
Battle	Dynamic, Explosive
Game Over	Sad, Sorrow
Victory	Happy, Fanfare, Cherry

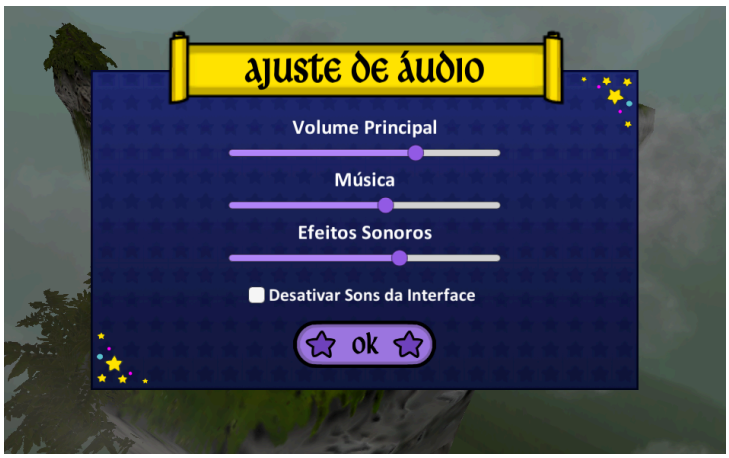


Figure 31 Audio Configuration Screen

Also, sound effects were used to enhance player's experience. Elements as explosions and magic effects were synchronized with appropriate

[35] Open Game Art Org, opengameart.org

sounds. Additionally, interface interactions like button clicks and key strokes triggered sound effects as well accordingly to its behavior, like confirm and cancel actions performing different sounds. The player could control the sound by pressing the audio configuration button at the top left corner of the screen anytime during the game. The user could adjust master, music and effects volumes and mute interface sound feedback (Figure 31).

For the Android version of the game, a haptic response was implemented on all player's touch and special effects. Unfortunately, the iOS version's haptic feedback could not be applied.

4. PROTOTYPE USER TESTS

4.1. Participants

For the user tests, 40 students were chosen from an elementary and middle school in Manaus, State of Amazonas, Brazil. These students were randomly separated into two groups: one group played the game prototype during the period of 30 days and the remaining 20 children were the control group.

The Educational Unit of the Industry Social Service (SESI) is a special school for Manaus' Industrial Pole workers' children (SESI, 2012). It's not a public school, but not private either. It is sustained by the National Industry Confederation and offers a low cost education for industry workers and their kids. Non-industrial workers' children can also study in SESI schools, but have to pay the full tuition.



Figure 32 Test sessions

The reason to choose SESI School is related to its infrastructure. A public school was the first option, but none could be found with appropriate computer laboratory and Internet connection, a key feature for the game should run on web browsers. The prototype was developed to run in almost any computer and slow Internet, but the condition of public schools in Manaus

regarding IT infrastructure is really problematic. SESI School offered a very good computer lab (Figure 32) with Internet good enough to run the game and perform the tests.

The game prototype was first presented to a team of the SESI School's Mathematics teachers and pedagogue who helped define game difficulty level and the best grade to test the game. The participants were 22 boys and 18 girls (Figure 33) from 11 to 13 years old (Figure 34) Brazilian 7th grade students living in Manaus, state of Amazonas.



Figure 33 Participants' Gender Distribution

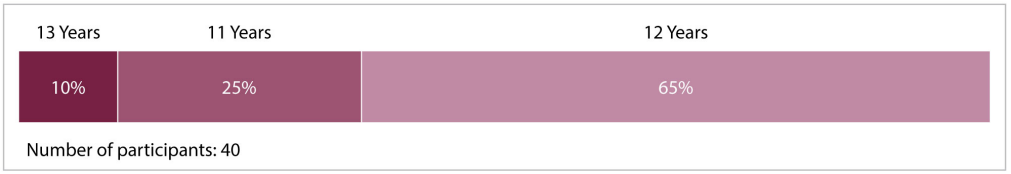


Figure 34 Participants' Age Distribution

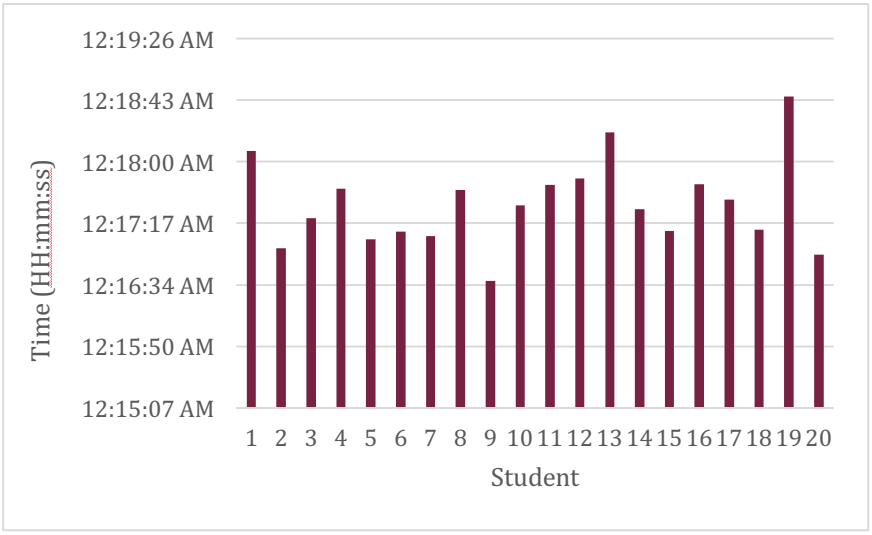


Figure 35 Average Individual Playtime

The students played the game prototype every day for 30 days during an approximate average time of 17 minutes per day between January

and February 2015. All students in this sample spent 4 hours in school and although the groups were randomly assigned, the treatment group students were from morning shift while the control group attended the afternoon classes[36].

The informatics laboratory was available for the participants during classes break time, allowing them to play 5 rounds or sessions per day in a total of 150 sessions per student. Students could also access the game from home via website. During all period of testing, both groups took the regular Mathematics classes, but only the treatment group played the game prototype. The groups were presented with the same Mathematics subjects with equivalent time to study and did the same paper exam in the end of the experiment.

4.2. Procedures and Instruments

This research used an experimental, posttest-only control group structure with quantitative method to data collection (Meredith D. Gall, 2003). A game server collected game data and stored it in a MySQL database. The Mathematics teachers applied the posttest after the period of game testing with the two groups. The posttest applied was the regular Mathematics exam for the first third of the semester, been the same for all students, including non-participants.

The game sessions' data were sent to an online server, which contained two database tables (Appendix B). The first table with students' personal info was used to authenticate the user's credentials (student name and ID) and grant access to the game. The second table received the player's score and playtime statistics, also registering the date and time of each session.

Before the experiment period, SESI School's teachers and pedagogues were consulted about best approach for applying the research's tests, target audience and sessions duration. In the first play session students were explained about the research's goals and the game prototype. After the test period of 30 days, the database's data was downloaded and analyzed. The game is still available for students, but without the data collection system.

[36] In Brazilian educational system, schools can either offer morning, midday, afternoon or full-time period classes. The morning-afternoon model is the most commonly find.

4.3. Data Analysis

This section will cover the statistical tests and analysis over the main research problem and two secondary questions. The posttest score of the treatment group was compared with the control group to determine whether the Instructional Contextual Teaching and Learning-based Game had any effect on students' performance. To support this research question, the game score and Mathematics score were compared in the treatment group. Also, in a secondary part of the study, the subjects' performance on game was compared to the time spent playing the prototype.

4.3.1. Main Investigative Question

Although the game prototype was developed with the basis of Contextual Teaching and Learning and Instructional Design, more specifically the REACT (Crawford, 2001a) and ARCS (Keller, 2009) models, there is no intention on measure such specific components on subjects, since this study assumes its effectiveness (Klein, Freitag, & Wolf, 1990; Klein & Freitag, 1991; Huett, 2006; Huang, Johnson, & Han, 2013; Woo, 2014). The main goal here is to measure the students' performance ono Mathematics using the game prototype against the students that only attended regular classes. With that clarified, the following research question was formulated:

- *Does an instructional contextual learning-based game have any effect on students' learning?*

The given problem requires two alternate hypotheses to be answered. In essence, there are two possible relationships in the outcomes: the difference between the posttest mean for the two groups and the correlation between the game score and Mathematics exam score. The first null hypothesis towards this inquiry answer was stated as follows:

- H_o1: *There will be no significant difference between the control group and the treatment group regarding the posttest score*.

In order to test the first hypothesis, the two groups' Mathematics exam scores means were compared as seen in the next chart. The maximum score possible for both groups was 10.0. The mean score for the treatment group was 8.7 and the standard deviation was 0.8. For the control group, mean was calculated as 7.7 and the standard deviation 0.1:

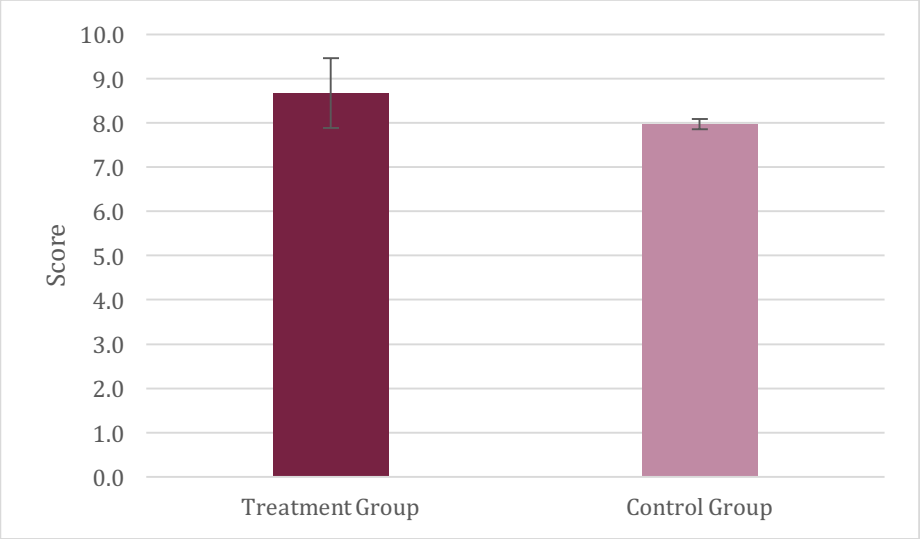


Figure 36 Subjects' Mathematics Score

As a result, the null hypothesis was refused as an *Independent T-Test* pointed $p < .001$, and the graph showed that the variability was also significantly distinctive. The treatment group showed a high variability while the control group presented a low variability. Whether this difference is related to game testing this research could not be investigated.

The second part of the research question solution involves relating the posttest score with the game score. An alternate hypothesis followed the assumption that the performance of the subjects inside the game could be directly related to their performance in the Mathematics exam, indicating a learning progress affected by the game mechanics and its instructional and educational features. This alternate premise was tested by its null counterpart bellow:

- H_o2: *There will be a week correlation between the game score and the posttest score*.

A simple correlation gave R-value of .92 as showed in the next chart evidently refusing the second null hypothesis. Now is possible to assume that there's a high probability that the game score is related to the Mathematics exam results.

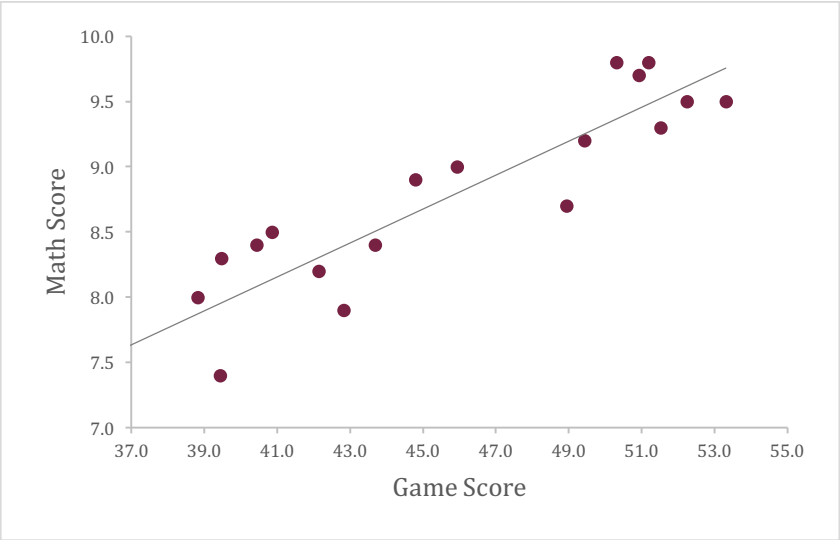


Figure 37 Mathematics score and game score correlation

As the two null hypotheses were refused, it is possible to assert that the answer to the main investigative question is *yes, Instructional Contextual Teaching and Learning-based Games can effect students learning*.

4.3.2. Playtime and Score

In the second part of the research investigated the relationship between the time subjects spent on playing the game prototype and their scores on both, game and Mathematics test. This investigation has raised two more research questions:

- *Does the playtime have any effect on students' game performance?*
- *Does the playtime have any effect on students' Mathematics performance?*

To address the first investigative question, the following null hypothesis was given and tested:

- $H_0$3: *There will be a week correlation between treatment group's total playtime and their game score*.

The given correlation with an R-value of .03 has confirmed the null hypothesis showing that the probability of effect of time played over the learner's game score is low.

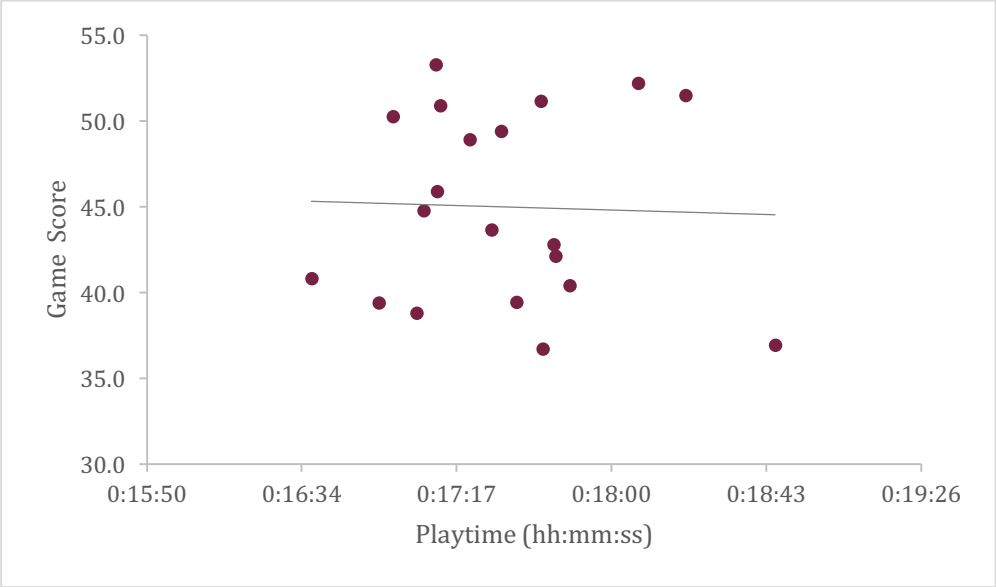


Figure 38 Game Score and Playtime Correlation

Moving to the second question, a similar null hypothesis was formulated and tested, this time regarding the subjects' posttest score:

- $H_0$4: *There will a week correlation between treatment group's total playtime and their Mathematics exam score*.

And similarly to the previous test, the analysis has found a low probability of correlation as the R-value returned .016:

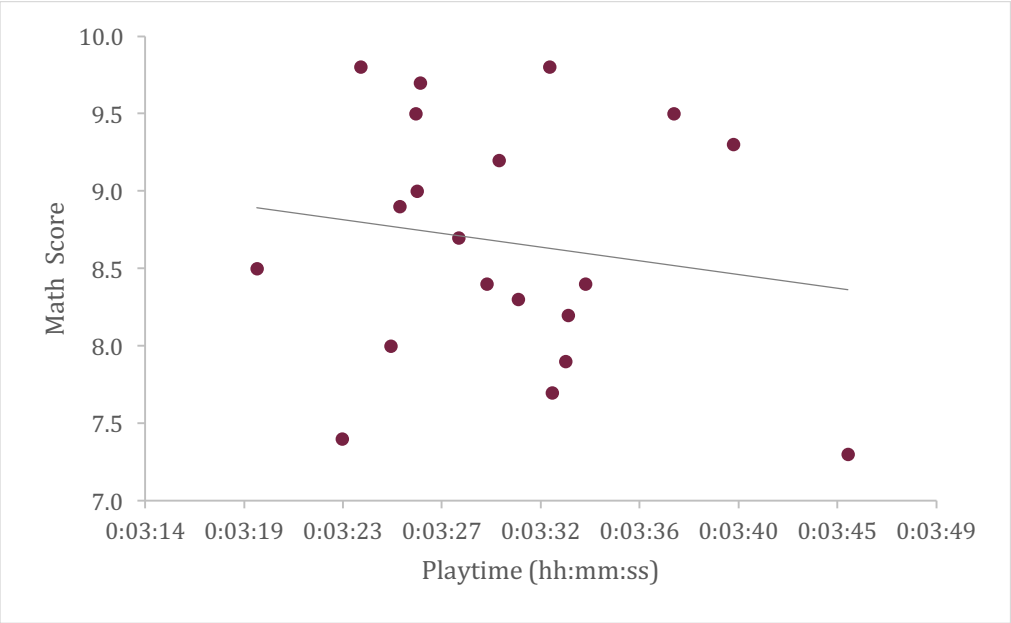


Figure 39 Mathematics Exam and Playtime Correlation

Thus, the second null hypothesis was confirmed as well. This way it was conclusive that the time that students played the game during the period of tests had no effect on their game scores nor on their Mathematics exam performance. Therefore, the answer to both secondary investigative questions is *no*. It is very important to note, however, that these secondary questions are strictly related to the game prototype developed specifically for this experiment and consequently, the presented answers apply only to proposed Instructional Contextual Teaching and Learning-based Game and its features.

4.4. Results

After the applied user tests, some findings are worth noting in order to fulfill the research objectives. In this section we covered the experiment with 40 7th grade students from Manaus, Brazil. The subjects played the proposed game prototype for 30 days and answered a posttest represented by a regular Mathematics exam.

Treatment group's performance on Mathematics were clearly improved by the proposed prototype gameplay, according to the findings in this section. The Instructional Design combined with Contextual Teaching and Learning approach proved to be effective as basis for the ARCS-REACT

model that can be applied in future projects and researches. The following table summarizes the set of hypotheses tested in this section:

Table 12 User Test Hypotheses

HYPOTHESIS	TRUE
There will be a significant difference between the control group and the treatment group regarding the posttest score.	O
There will be a strong correlation between the game score and the posttest score.	O
There will be a strong correlation between treatment group's total playtime and their game score.	X
There will a strong correlation between treatment group's total playtime and their Mathematics exam score.	X

Based on these tested assumptions, we can conclude the following:

- Instructional Contextual Learning-based games can be effective on students' improvement;
- There's a low probability of students' game performance to be affected by how long they play the game;
- There's a low probability of students' Mathematics exam performance to be affected by how long they play the game.

These results, however, need an additional support to confirm or not the main research hypotheses and answer the central investigative question. The next chapter will cover the ARCS-REACT relationship with the proposed prototype and other educational and non-educational games available on the market.

5. ARCS-REACT and Educational Games

The final part of this work is the comparison between educational games, commercial games and the proposed model. In this section ten selected games will be compared with ten selected commercial games through an online questionnaire with Brazilian players. Also, the game's features will be correlated with the ARCS-REACT in order to identify weak points and advantages. An overview on educational game's market is presented lastly aiming a macro understanding of this study's findings.

5.1. Methods and Procedures

This final part of this research comprehends three distinct steps. First, the attractiveness of educational games was compared to commercial games with Brazilian players. Secondly, educational games' features were compared with the ARCS-REACT model. Finally, the educational game market was briefly analyzed.

Empirically observing, educational games are, in general, not as attractive to players as commercial games. The reason may vary from limited project budget to lack of researches regarding educational games' design and development. Most games with educational purposes are low quality applications, poorly designed as games and working more as interactive supporting material (Oksanen, Hämäläinen, Mannila, & Manninen, 2010). This low appealing feature is a huge barrier for games that can really change educational process for the future.

Following this line and expecting to better establish the heuristics for attention in the ARCS-REACT approach, a brief study was conducted and will be discussed in this chapter. The objective was to determine which aspect of online educational games are responsible for its lack of attractiveness in comparison with commercial non-educational games. In order to guide the study presented in this chapter, the following set of hypotheses were formulated:

- H_a1: *Players prefer to play non-educational games*.
- H_a2: *Players perceive educational games' quality as poor*.
- H_a3: Matemagos prototype is most adequate game to the ARCS-REACT model.
- H_a4: Educational games market is not growing.
- H_a5: Educational games market share is too small.

At first simple questionnaire was applied with 60 Brazilian players, between 13 and 45 years old from June 20th and 27th, 2015. A qualitative and quantitative approach was used to analyze the data. The original questionnaire in Portuguese is available in Appendix A. During the questionnaire, players were asked four main questions as follows:

- What is the most attractive aspect of a video game?
- What do you think about educational games' quality?
- Which game would you like to play more?
- Why?

Before answering the last two questions, the respondents should analyze random images of ten educational games, to be presented in the next section, and ten non-educational games plus the Matemagos prototype.

In the next step, the same ten educational games used in the previous questionnaire were compared to the ARCS-REACT model categories. Each game received a grade from 1 to 5 for each category, assuming every game has at least a basic concept of ARCS-REACT. For instance: even if a game does not come with online capabilities, it will still be possible to find the Cooperating category, since the player can always ask a friend to play together. In that case, the game would receive just 1 point for that specific category.

The final part of this chapter is a brief overview about the Learning-based Game's market compared to the general game industry. It is significant to help understand the importance of this work and the future researches with similar goals.

5.2. Top Educational Games

First of all, ten educational games were chosen and are presented in the following sub-topics. This list is based on the 2014 ON for Learning Awards (Common Sense Media, 2014) and contains educational games and commercial games with important educational features. The goal here is to understand some features of the evaluated games and compare them with the ARCS-REACT model. The non-educational games won't receive the same analysis because they won't be compared with the proposed model.

Some games on Learning Awards list were skipped. The 6th placed Little Big Planet, a PlayStation Vita game published by Sony Computer Entertainment was removed from the comparison study because it's not entirely educational. In the game, the *creator* mode is where most of the learning principles applies, while the main part of the game is focused on platform action. Another exception is the Monkey Tales game series. All games on that series were in the Common Sense Media list and to avoid include many similar games on the research, only the best placed game was chosen.

5.2.1. Algodoo

It is a physics simulation game for Mac OSX, Windows and iPad where kids can explore a wide range of possibilities to create playable scenarios. *Algodoo* uses scientific concepts to encourage kids to understand the world throughout their own inventions in-game, as light, gravity, magnetism, friction and so on.

According to the reviewer "kids play as engineers, inventors, and scientists exploring (and building with) the cause-and-effect relationships among energy, objects, and materials." (Sansing, 2014). Algodoo (Figure 40) was released on September 1st, 2009 by *Algoryx* and is rated with 5 stars by Common Sense Media. *Algodoo* offers tutorials that help kids master the game basics and there's many projects in the game's community that can help players achieve more complex and advanced scenarios, promoting a very comfortable learning curve. The following table shows the learning rating details:

Table 13 Algodoo Learning Ratings (Sansing, 2014)

SUBJECTS	SKILLS
Language and Reading: following directions.	**Thinking and Reasoning:** defining problems, hypothesis-testing, problem solving.
Math: algebra, arithmetic, geometry	**Creativity:** developing novel solutions, making new creations.
Science: engineering, measurement, physics	**Self-Direction:** goal-setting, self-assessment, work to achieve goals.
Arts: drawing	**Emotional Development:** developing resilience, persevering.
Hobbies: building	**Collaboration:** meeting challenges together.
	Tech skills: digital creation, using and applying technology.

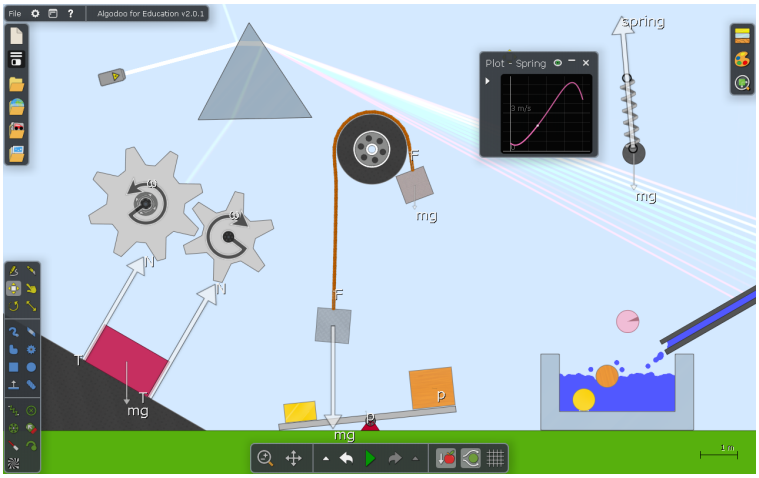


Figure 40 Algodoo Screenshot

Although its easy to start playing around with the interface, some tutorials are needed to achieve more complex scenarios. Because of that and for scariness a blank canvas may cause, the game fails a bit in the Attention and Relevance aspects. The lack of clear goals is a good and common feature of any sandbox game, but it definitely goes against the ARCS-REACT approach. Another weakness observed is a lack of rewards for players and the ability to share these conquers. By the other hand, the game gives a high level of Confidence, Relating and Applying, for players can easily relate the game mechanics with the physical world, what contributes to the sense of control.

Cooperating could be better. The game has a very solid online community, but it could be better integrated with the game mechanics.

5.2.2. Brain Age Express: Arts and Letters

This Nintendo DSi puzzle game released in 2009 is focused on language and drawing. As the other games on the Brain Age series, the application is based on brain-training activities developed by Dr. Ryuta Kawashima. This title covers language, letters, spelling and art with many puzzles from scrambled letters rearrangement to photo recall. The complete table of subjects and skills can be seen bellow:

Table 14 Brain Age Express Learning Ratings (Bell E. , 2010)

SUBJECTS	SKILLS
Language and Reading: letter or word recognition, reading, spelling.	**Thinking and Reasoning:** memorization, solving puzzles.
Math: sequences, patterns	**Self-Direction:** goal-setting, self-assessment, identifying strengths and weaknesses.
Arts: drawing, music, photography	**Communication:** listening, multiple forms of expression, speaking.
	Tech skills: using and applying technology.
	Health and Fitness: fine motor skills.

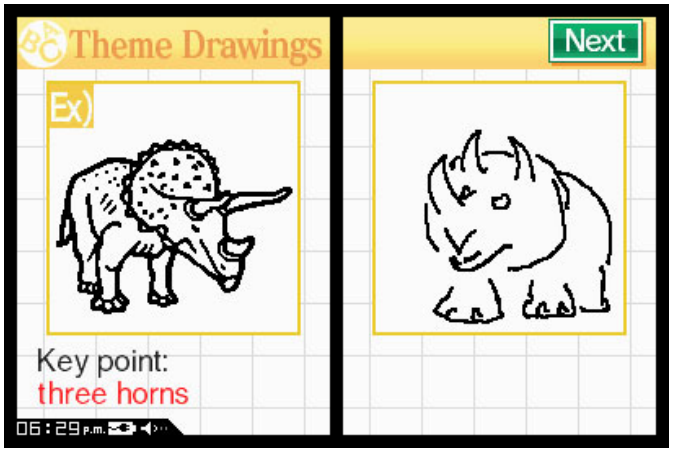


Figure 41 Brain Age Express Screenshot

Brain Age Express: Arts and Letters (Figure 41) is a download-only game published by Nintendo. It makes good use of Nintendo DSi hardware technical capabilities, as camera and accurate stylus pen.

5.2.3. Dora's Cooking Club

This kitchen simulator developed by 2K Play and published for Nintendo DS and DSi in 2010 teaches math with cooking recipes. During the gameplay, kids have to chop vegetables, stir soups top pizzas, mix ingredients, etc. For the game reviewer at Common Sense Media organization, "it's a very appealing game that will draw kids in with its colorful, positive vibe (…), and will keep them interested and having fun as they practice their arithmetic."

Table 15 Dora's Cooking Club Learning Ratings (Healy, 2012)

SUBJECTS	SKILLS
Language and Reading: following directions.	**Communication:** listening.
Math: patterns, counting, fractions	
Hobbies: cooking	



Figure 42 Dora's Cooking Club Screenshot

The table above describes the learning ratings of the game. It helps children to learn the basics of arithmetic and some more advanced subjects as measurement and fractions.

The game also counts with a background story that contributes to its contextualization. In the game story, the player must help Dora to prepare dishes for the Favorite Food Festival. The character helps many adults to prepare more than 30 recipes along the game. Thanks to this background and the fact that each recipe is taught by an adult, it is possible to say that Dora's Cooking Club presents high levels of Attention, Relevance, Confidence, Relating, Experiencing and Appling, almost all ARCS-REACT categories. Satisfaction could be improved, but is present in a very interesting way throughout parents can check children's progress, what can lead to awards out of the game. This feature also contributes with the Cooperation and Transferring, but again no complete online solution was found in the game.

5.2.4. Kinect Nat Geo TV

This nature-themed interactive TV game uses the Microsoft's Kinect technology to put the players inside a TV show. It features the naturalist Casey Anderson as host and takes players to animal habitats over the world. The game developed by Microsoft Studios for the game console Xbox 360 was released in September, 2012.

Table 16 Kinect Nat Geo TV Learning Ratings (Sapieha, 2012)

SUBJECTS	SKILLS
Science: animals, life cycle.	**Thinking and Reasoning:** collecting data, investigation.
	Collaboration: meeting challenges together.

As we can see in the previous table and according Chad Sapieha, the game reviewer for the Common Sense Media, children can learn about many animals' behaviors, diets, habitats and more. "They also glean an

understanding of how these animals fit into our modern world, and see how humans are helping certain species propagate and thrive." (Sapieha, 2012).



Figure 43 Kinect Nat Geo TV Screenshot

As the name suggests, the game is based on National Geographic TV programs and combines it with the motion sensor, camera and microphone device Kinetic to create an interactive experience. This way children can engage on the TV show with gesture and voices. All this interaction promotes an elevated level of Attention, Relevance, Relating, Experiencing and Applying. As it works more as an application than a game, the Confidence is compromised here. By the other hand, the Xbox Achievement system works very well as a reward for a better Satisfaction. Cooperating is good for players can share the screen during the activities, but it could be better achieved with more online features, what could also improve the Transferring aspect of ARCS-REACT model.

5.2.5. Cooking! Recipes on the Road

Another cooking game on the Common Sense Media list also uses a kitchen simulation to teach mathematics, similarly to Dora's Cooking Club. However, *Recipes on the Road* is a game developed by LeapFrog to run exclusively on their proprietary devices, the tablets *LeapPad Explorer, LeapPad Ultra, LeapPad 2* and *LeapsterGS*. This 2013 game was reviewed by Christy Matte with the following learning ratings:

Table 17 Recipes on the Road Learning Ratings (Matte, 2013a)

SUBJECTS	SKILLS
Language and Reading: following directions.	**Thinking and Reasoning:** decision-making, part-whole relationships.
Math: arithmetic, fractions, measurement.	**Self-Direction:** work to achieve goals.
Hobbies: cooking.	

Children can also learn how to manage a food truck business. In that sense is a very contextual game by showing the importance of mathematics on everyday life. Additionally, kids have to clean the kitchens and recycle.



Figure 44 Cooking! Recipes on the Road Screenshot

The *LeapFrog's* game has a very well balanced difficulty level and learning curve. Its integration with mathematics is quite natural and the game brings other important subjects as knife safety, hand washing and securely use of the stove.

Comparing the game with the ARCS-REACT categories, Recipes on the Road shows great levels of Attention, Relevance, Confidence, Relating, Experiencing and Applying, covering almost every single category on the proposed model. However, the game lacks of ways to Cooperating and Transferring and the Satisfaction is left to the in-game achievements, what's

not totally bad, since the game explores very well the sense of entrepreneurship and business.

5.2.6. Minecraft

This open-world sandbox game, originally created by Markus Person and continued by Jens Bergensten, is one of the most successful indie games of all time. Despite a beta release in mid 2010, which attracted millions of players, the was officially released in April, 2011.

Table 18 Algodoo Learning Ratings (Sapieha, 2011)

SUBJECTS	SKILLS
Math: estimation, geometry, shapes.	**Thinking and Reasoning:** defining problems, hypothesis-testing, problem solving.
Science: geology, rocks and minerals	**Creativity:** imagination, making new creations, producing new content.
Hobbies: building	**Collaboration:** cooperation, group projects, teamwork.

The Common Sense Media reviewer Chad Sapieha points out that children can learn about geometry and develop a creative thinking, as seen in the table above. The game focuses on build block structures in open-world 3D environment, encouraging a very imaginative and creative exercise.



Figure 45 Minecraft Screenshot

The reviewer continues explaining that the game starts with no instructions, promoting a learning curve from discovery and experimentation, what can lead some less patient players to abandon the application prematurely. Minecraft is available to a wide range of platforms, including Windows, Mac OSX, Linus and Xbox 360.

Similar to Algodoo, the *empty canvas* or, in this particular case, the vastness of world may lead to a lower index of attention. However, the visual appealing scenario is an invite to creation. Minecraft's huge online community contributes to the high level of Cooperating and Transferring while its Achievement System grant Satisfaction a very good ranking. Confidence may be compromised by the subjective sense of success that the game implies.

5.2.7. Mission US: A Cheyenne Odyssey

In this adventure game, the player controls a Cheyenne boy in the late 1800s until his adulthood, trying to help his people and survive. The game available for Mac OSX, Windows and Web, was published by Thirteen/WNET in 2013 and explores the Native American culture and their relationships with settlers and the U.S. government in late 1800s. This rich experience can develop the following set of subjects and skills:

Table 19 A Cheyenne Odyssey Learning Ratings (Matte, 2013b)

SUBJECTS	SKILLS
Language and Reading: vocabulary.	**Thinking and Reasoning:** applying information, decision making.
Social Studies: cultural understanding, historical figures, history	**Emotional Development:** empathy, perspective taking.
	Responsibility and Ethics: making wise decisions, honoring the community, learning from consequences.

A Cheyenne Odyssey gives the player a very unique perspective of a historical period. During the game, the player's decisions affects the character and the community, creating an extremely social-critical experience.

Thanks to its thinking gameplay, children can play the game over again trying to make different decisions and learn from its consequences. Following this direction, players can connect more with characters and community build their own cultural and ethical experience.



Figure 46 A Cheyenne Odyssey Screenshot

A Cheyenne Odyssey is a very contextual game with nice looking visual, but the player can't explore the world freely. The compensation is a deep storyline based upon players' choices, what makes Attention, Relevance and Satisfaction very well rated. Experiencing is low for the lack of exploring and Cooperating and Transferring could be better represented with online capabilities.

5.2.8. Monkey Tales: The Abbey of Aviath

Exploring magic and fantasy, this action-adventure game focus on enforcing math lessons learned in school. It belongs to a series of educational games series by Monkey Tales Games released in 2011. The following table shows the game set of learning ratings:

Table 20 Monkey Tales Learning Ratings (Koh, 2011)

SUBJECTS	SKILLS
Language and Reading: reading.	**Thinking and Reasoning:** logic, solving puzzles.
Math: multiplication, subtraction, addition, arithmetic, division, fractions	

According to the game reviewer Carolyn Koh, kids can learn 4th grade mathematics throughout the gameplay and its scenarios. “As they adventure through the game, they will use logic to navigate mazes and practice their math skill as they play the mini-games they find.” (Koh, 2011).



Figure 47 Monkey Tales: The Abbey of Aviat Screenshot

Differently from the previous game, the Mokey Tales series is full of world exploring and puzzle solving. These features in combination with beautiful graphics and interesting storyline turns it a great game for the ARCS-REACT model. Attention, Relevance, Confidence, Relating, Experiencing and Applying are all well rated, leaving Cooperating and Transferring in a low level. Satisfaction is just overall due to its dependence only on in-game awards.

5.2.9. Ni Hao, Kai-Lan: New Year's Celebration

One more game for the Nintendo dual screen game systems DS and DSi and one more from 2K Play. Released in November, 2009, Ni Hao, Kai-Lan: New Year's Celebration puts the player in preparation and celebration of a Chinese New Year festival.

Table 21 Ni Hao, Kai-Lan Learning Ratings (Healy, 2009)

SUBJECTS	SKILLS
Math: patterns, sequences, shapes.	**Emotional Development:** empathy, identifying emotions, moving beyond obstacles.
Social Studies: cultural understanding.	**Communication:** listening.
Arts: rhythm	**Collaboration:** cooperation, respecting other viewpoints, teamwork.

According to the reviewer, the game helps with educational and emotional development. The game also offers a contextualization through a background story that leads players to better understand the Chinese culture and music.



Figure 48 Ni Hao, Kai-Lan Screenshot

Ni Hao, Kai-Lan brings a good storyline full of fun. Because of that and because the game makes good use of the 3DS technical features, Attention is very high. The game also comes with good balance between

Relevance, Confidence, Relating, Experiencing and Applying. Satisfaction is open to improvement and once again, Cooperating and Transferring are very critical.

This is very engaging game for kids, promoting the feeling of taking part in a cultural festivity and uses the technological resources of Nintendo DS and DSi system for an improved gameplay experience.

5.2.10. Re-Mission 2

The last game in the list is an action-adventure game for Mac OSX and Windows released in 2013 by HopeLab. In fact it's a suit of six free games exploring cancer treatment in a variety of action gameplays. Strongly focused on science and nature, the learning ratings of the game are listed in the following table:

Table 22 Re-Mission 2 Learning Ratings (Sapieha, 2013)

SUBJECTS	SKILLS
Science: biology.	**Thinking and Reasoning:** logic, problem solving, strategy.
	Emotional Development: empathy, handling stress, persevering.
	Health and Fitness: preventing sickness.



Figure 49 Re-Mission 2 Screenshot

Each game in this set brings a distinct gameplay. For instance, the *Nanobot's Revenge* put the players defending lungs and blood vessels using weapons as *Radiation Beans* while *Nano Dropbot* is a side-scrolling fighting cancerous creatures to rescue healthy cells.

Re-Mission 2 follows the acclaimed 3rd person shooter game Re-Mission about the same theme. Is very polished set of games, simple to learn despite of its variety of game mechanics and exciting to play.

The game is very attractive to player's attention, but its variety of mechanics may be intimidating, avoiding Attention to be better rated. But the game does quite well on Relevance, Confidence and Relating. Applying that knowledge is a little bit complicated for the game mechanics doesn't reflects the human body functions properly using monsters and other metaphorical creatures and structures. Of course, Cooperating and Transferring would be great with online features and Satisfaction lacks of an appropriate award system.

5.3. Games' Attractiveness Test

In order to understand the perception of players about educational game's attractiveness, the ten games just listed plus the *Matemagos* prototype, were compared with non-educational, commercial games. These games were chosen from the 2014 Best Overall Games list from IGN Best of 2014 Award (IGN, 2014) as seen in the following table:

TITLE	DEVELOPER	PUBLISHER
Dragon Age: Inquisition	Bioware	Eletronic Arts
Child of Light	Ubisoft Montreal	Ubisoft
Shovel Knight	Yacht Club Games	Yacht Club Games
Hearthstone	Blizzard Entertainment	Blizzard Entertainment
Shadow of Mordor	Monolith Productions	Warner Bros Interactive
Super Smash Bros Wii U	Bandai Namco Games	Nintendo
Transistor	Supergiant Games	Supergiant Games
The Stick of Truth	Obsidian Entertainment	Ubisoft
Sunset Overdrive	Insomniac Games	Microsoft Game Studios
Bayonetta 2	Platinum Games	Nintendo

As seen in the section 6.2, an online questionnaire was applied with 60 Brazilian players from 13 to 45 years old during a period of one week in June of 2015. It is important to understand that this survey was not intended to evaluate the games' quality but the perception of players about it. Secondly, the term quality is here being applied as a set of game's features not restricted to graphics and visual effects, but also extended to music and sound effects, background story and sociability.

The questionnaire, as seen in the Appendix A, was composed of four main questions. The first interrogation was "what is the most attractive aspect of a video game?". The next graph shows that the majority of players finds gameplay the most attractive feature in a game followed by story and graphics. Music and sound effects and sociability received one vote each.

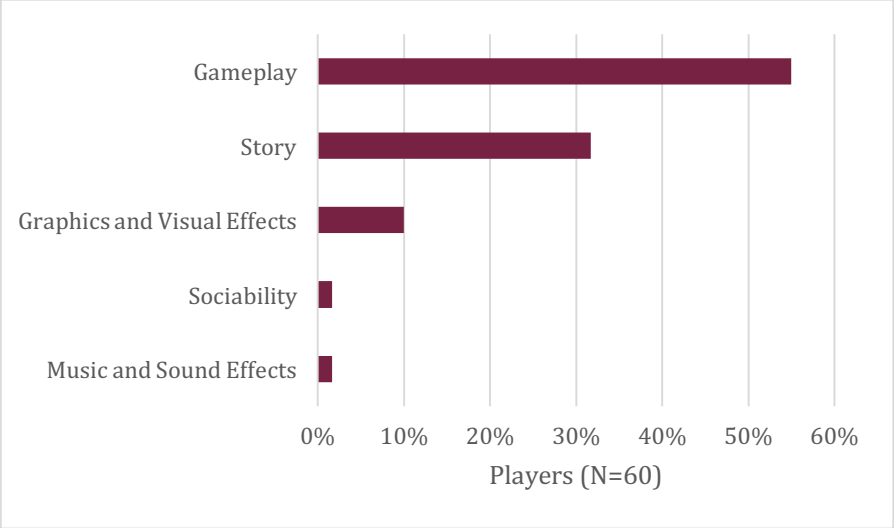


Figure 50 Game's Most Attractive Features

It is observed that, from the player's perspective, game mechanics have a great impact on attracting people to play it. It's not uncommon to see low graphic appealing games become a massive success due to its well designed gameplay. The second question is about the player's impression on educational game's overall quality. The sentence was placed as "what do you think about educational games' quality?" and the summarized results are shown in the following chart:

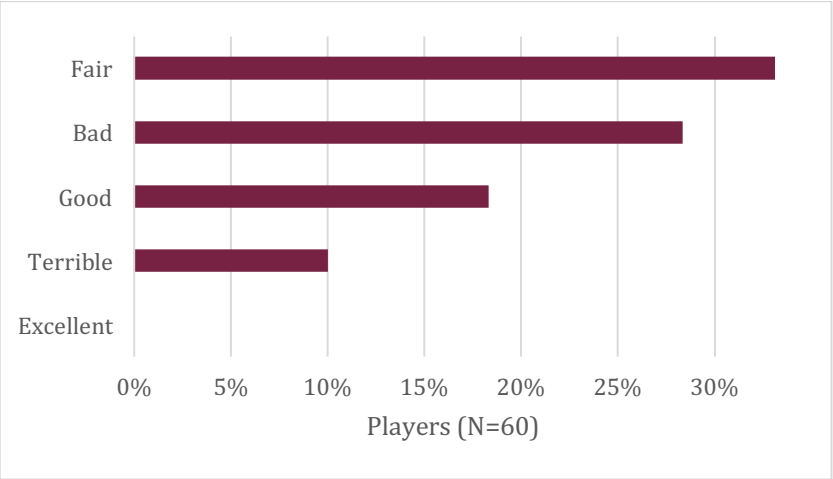


Figure 51 Player's Perception on Educational Game's Quality

Most of respondents (61%) perceive educational games' quality as fair or bad. Only 18% have the idea of digital learning games' quality as good. In general, game players believe that educational games are poorly developed and designed. The reason may come from low budget and tight deadlines, but the real state of educational games' market should be discussed further.

The next question was about player's choice between educational and non-educational games. In the questionnaire, the respondents should choose between two games randomly displayed from the list with 10 educational games and 10 non-educational games plus the game prototype *Matemagos*. Player's were asked also the reason for their choices. The next few graphs show the results. First, let's take a look into each game's performance:

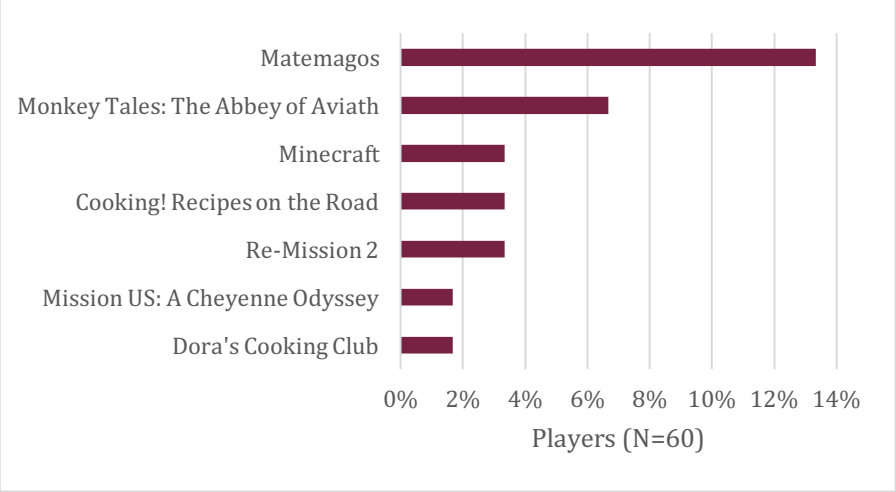


Figure 52 Top Educational Games

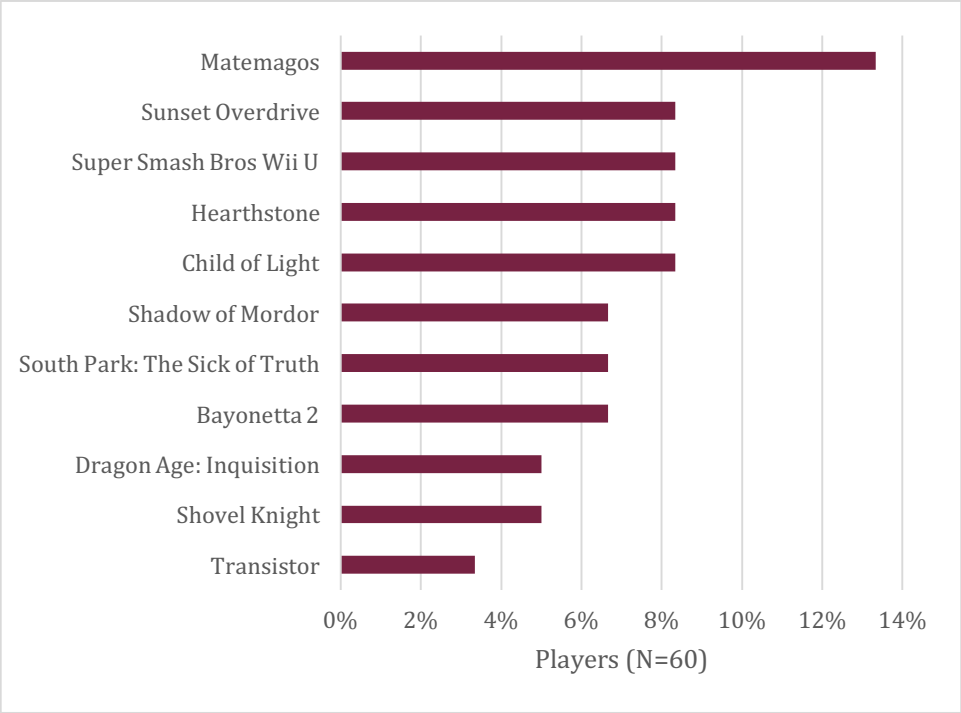


Figure 53 Top Non-educational Games

It's possible to notice that the proposed prototype, Matemagos, was best voted against both lists with a significant difference. Moreover, most of players preferred to play a non-educational commercial game, as shown in the next chart:

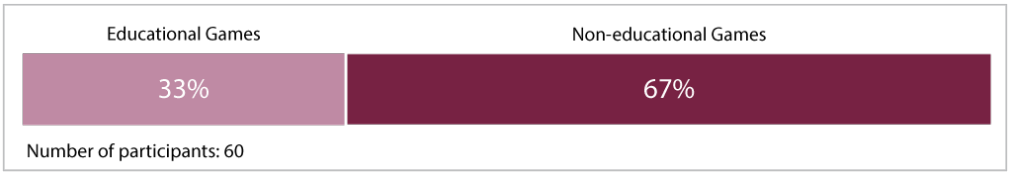


Figure 54 Educational Vs. Non-Educational Games

In the universe of 60 respondents, 67% has chosen a non-educational game to play instead of a learning-based one. When asked why they would pick up that specific game, the majority answered that the graphics and visual was the most important factor, followed by game style as seen in the next graph:

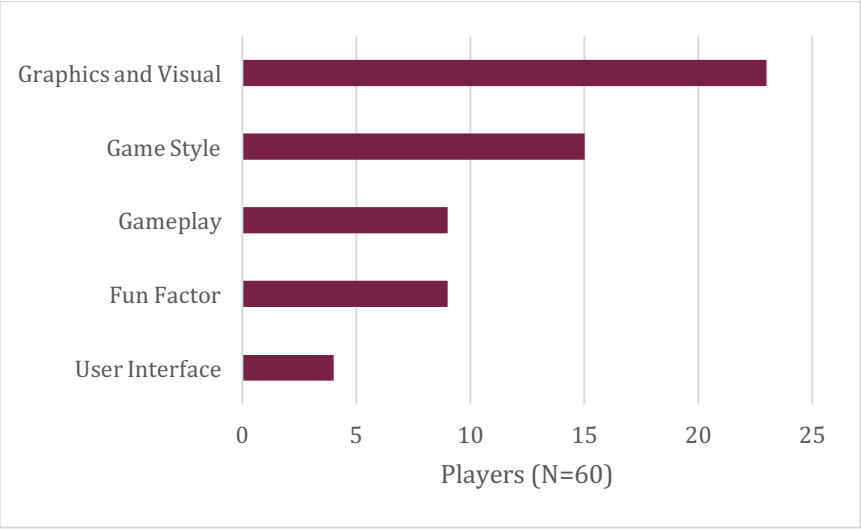


Figure 55 Players' Reason for Choosing a Game

Differently from the first question, this time, the players confessed the graphics and visual aspect of the application were determinant upon their decision making. Also, this question was applied using a qualitative approach. It was not given the subjects options to answer but they were left free to write whichever reason they have considered appropriate. All the questions could be arranged into five aspects as seen in the last graph: *graphics and visual, game style, fun factor* and *user interface.*

5.4. ARCS-REACT Comparison

Moving on this last set of experiments, a comparative method was applied between the ARCS-REACT approach and the educational games presented in section 6.2. The objective is to evaluate the application or not of the proposed heuristics in the given educational games. In order to achieve this comparison, the games were played, evaluated and compared with the professional reviewers cited in the mentioned section (Common Sense Media, 2014). Additionally, the Matemagos game prototype was evaluated. To use the same criteria with observed games, a ARCS-REACT score was created based on its main categories. For each category, a set of heuristics were defined and a punctuation system provided. According to this scale, the ten educational games previously studied and the Matemagos prototype were evaluated. The next table explains the ARCS-REACT score scale:

Table 23 ARCS-REACT Scale

CATEGORY	POINTS
Attention	Easy Immersion (1 points) Good Storyline (2 points) Visual and Audio (2 points)
Relevance	Clear Goals (1 points) Gameplay Storyline (2 points) Personal Involvement (2 points)
Confidence	Control (2 points) Score and Status (1 points) Learning curve (2 points)
Satisfaction	Replay Factor (1 points) Achievements (2 points) Rewards (2 points)
Relating	Pop Culture (1 points) User Interface (2 points) Fun Factor (2 points)
Experiencing	Immersive World (3 points) Emotional Appeal (2 points)
Applying	Challenge Level (3 points) Challenge Progress (2 points)
Cooperating	Social Media (2 points) Competition (2 points) High Scores (1 points)
Transferring	Sharable Information (3 points) Social Interaction (2 points)

The next table summarizes the findings. For each one of the ARCS-REACT category, a rank from 0 to 5 was granted. As we can see in the next table, all the educational games carry some level of ARCS-REACT approach in it, but most of them failed in the *Cooperating* and *Transferring* categories:

Table 24 ARCS-REACT and Educational Games

GAME	A	R	C	S	R	E	A	C	T
Algodoo	3	2	4	2	4	5	5	3	4
Brain Age Express: Arts and Letters	3	2	4	4	4	5	5	2	3
Dora's Cooking Club	4	4	5	3	5	5	5	2	2
Kinect Nat Geo TV	4	4	3	3	5	5	5	3	2
Cooking! Recipes on the Road	5	4	5	3	5	5	5	1	1
Minecraft	4	4	3	5	4	5	5	3	4
Mission US: A Cheyenne Odyssey	4	5	5	3	4	3	3	1	1
Monkey Tales: The Abbey of Aviath	5	5	4	3	4	5	5	1	1
Ni Hao, Kai-Lan: New Year's Celebration	4	5	5	3	4	5	5	1	1
Re-Mission 2	3	5	5	3	5	4	3	1	1
Matemagos	5	4	5	4	4	5	5	3	4

By getting the average punctuation, the following chart was provided. Observe how close all games are in punctuation:

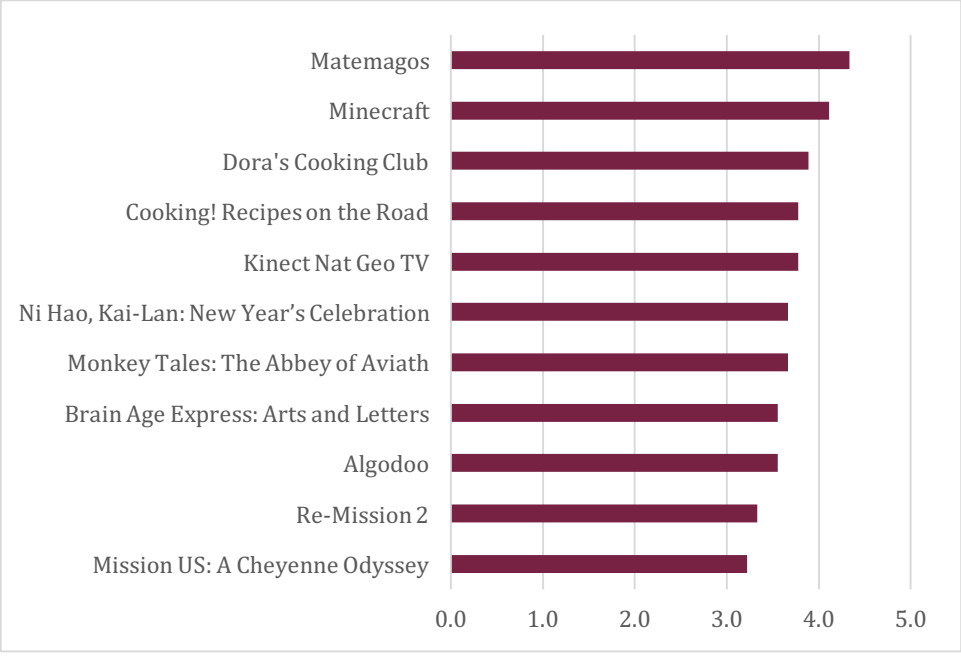


Figure 56 Edugames' ARCS-REACT Score

Matemagos prototype was developed with ARCS-REACT in mind and naturally would receive good punctuation. The card-game interface was designed to be intuitive and easy, based upon the Contextual Learning principles and the visual was polished to match AAA games. These aspects got Matemagos a very good grade in Attention. The JRPG mechanics gave the game also good levels of Relevance, Confidence and Relating while in-game associated with classroom rewards contributed to a well positioned Satisfaction. The integration between the game content and curriculum was critical to Experiencing and Appling and the online game capabilities alongside with its Website and Ranking system were used to improve Cooperation and Transferring.

5.5. Educational Games Market

Finally, it is time to take a look over the educational games market in order to better understand how this research can collaborate and improve it. Educational game market is growing and as any other video game sector, is growing fast. According to Ambient Insight report on Game-based Learning Market (Adkins, 2012), it is growing at a rate of 15.4% and will reach more than $2.5 billion in revenue by 2015. Adkins also demonstrates that Latin America market on Game-based Learning applications is growing even faster, as seen in the next chart:

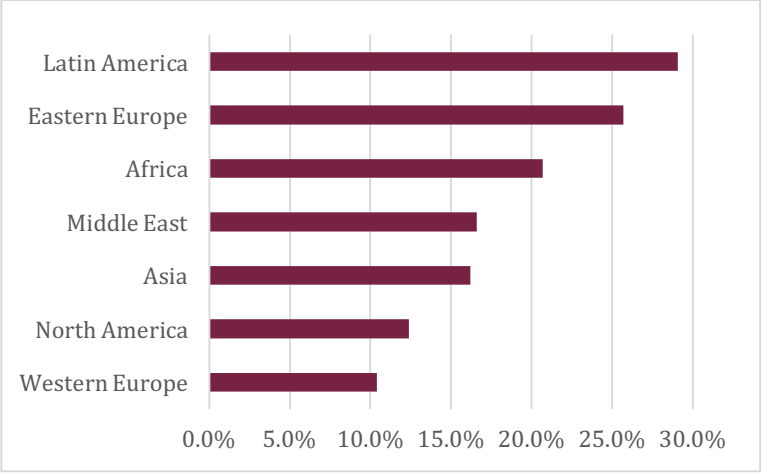


Figure 57 2011-2016 Worldwide GBL Growth Rates by Region

The author points that buying behavior is different for each country. For instance, despite of its low growing rate, revenues are heavily concentrated in China, South Korea, US and Japan. It is clear to see that educational games market is healthy and promising, but in comparison with other market shares, it represents only 3% of a $86.1 billion industry in 2016 (Newzoo, 2013).

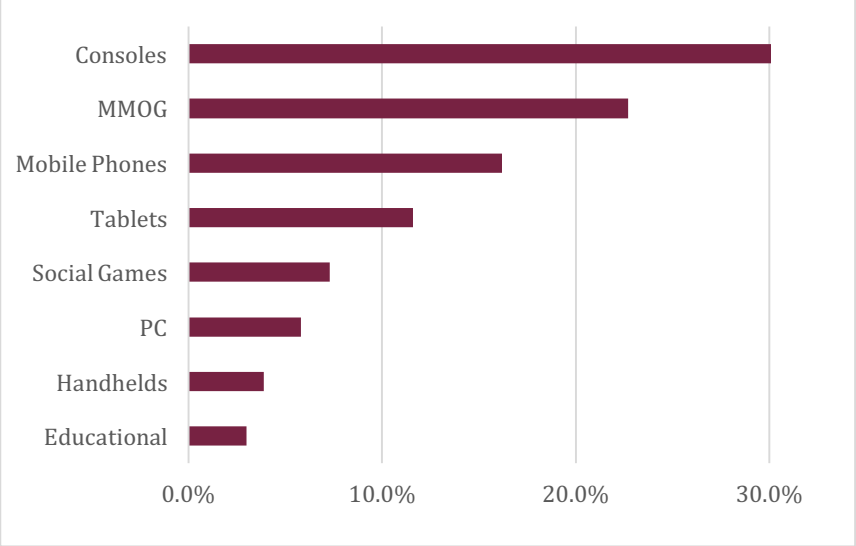


Figure 58 Games Market Share By Platform

Evidently the comparison between Edugames and platforms do not fit, but it illustrates how small is the Learning-based Games market despite its high growing rate. It means there's a big opportunity here. A fast growing market with a lot of room to expand.

5.6. Conclusions

After applying the online questionnaire, analyze the comparison between the educational games and the ARCS-REACT model and briefly look at Learning-based Games market, we can finally revisit the given hypotheses in search for some answers. This part of the investigation was important to give support to the main research. The next table summarizes the findings in this chapter and offers a good support on the main research questions as well, to be reported and discussed in the last and final chapter.

Table 25 Games Comparison Hypotheses

HYPOTHESIS	TRUE
Players will prefer to play non-educational games.	O
Players perceive educational games' quality as poor.	O
Matemagos the is most adequate game to the ARCS-REACT model.	O
Educational games market is not growing.	X
Graphics and Visual Effects are the most attractive game feature.	O

Based on the questionnaire results we can conclude that game players usually perceive educational games quality mostly bad and fair. Only 10% think about as excellent and 18% as good. Additionally, 67% of players chose a non-educational game to play. Based on these data, we can confirm the first to third hypotheses as listed in the Table 24.

Furthermore, it is possible to conclude that Matemagos game prototype was very suitable to the ARCS-REACT model in accordance to the evaluation demonstrated in the section 6.4. As a game designed with ARCS-REACT in mind, that result was expected.

About the Learning-based Games market it is quite clear that the market is growing and fast, therefore, our fourth hypothesis was refused. By the other hand, it was noticed that the market share represents only 3% of a robust $86.1 billion market, what confirms our last hypothesis and points toward a very promising future for edugames.

It is interesting to observe as a last note that despite most players said they think gameplay and story as the most attractive game attributes, in the end, they answered that Graphics and Visual Effects were the main reason for them to choose a game to play. This fact represents a very important guideline for future developments.

6. FINAL CONSIDERATIONS

After a long way of exploration, analysis and experimentation, this research resulted in some outcomes worth a few pages of discussion. This section will summarize this entire work and will address to its results and conclusions.

6.1. Research Summary

The research problem was addressed to fulfill the following goal: ***propose a conceptual model*** as a guideline to a Digital Game-based Learning design and development oriented but not restricted to developing countries' elementary students. In order to reach this goal, the following steps were performed:

- Define the key elements to an approach based on Instructional Design and Contextual Teaching and Learning theories;
- Create a guideline of development on top of the specified approach;
- Develop a Digital Game-Based Learning prototype;
- Test the prototype with elementary students.
- Compare the prototype with other educational games and with the proposed guideline;

To accomplish the goals listed above, a game prototype was developed and tested with a true experimental, posttest-only design with control group and quantitative method to data collection. For this experiment, 40 students were chosen from an elementary and middle school in Manaus, State of Amazonas, Brazil and randomly separated into treatment and control groups. After the test period of 30 days, the game sessions' data were sent to an online server and analyzed for statistical relevance and validation.

The theoretical framework was based on exploratory research over the and comparative methods upon the three principles used in the research

theme: Contextual Teaching and Learning, Video Games and Instructional Design. The results were organized in a series of heuristics called ARCS-REACT model.

For the prototype development study, four minor researches were conducted: prototyping tools, strategic interfaces, character design and prototype development. The brief description of prototyping methods and tools used a comparative method to establish the most viable and low cost tools suitable for fast development. This investigation resulted in a workflow model for character modeling and animation, image creation and processing, coding and sound editing.

The strategic interface for Digital Game-based Learning was a more complex study. In this auxiliary research, a comparative method was used to analyze four *Trading Card Games* and two *Card-based Game Interfaces* in order to list categories and features related to the theoretical framework proposed. These features were used to develop a game prototype based on a community-oriented design approach. The prototype presented two different User Interfaces: one with 10 cards based on Art History and another designed with buttons instead. 20 Brazilian users tested the prototype during 3 days. A true experimental, pretest-posttest design research with two groups method was used. The results have confirmed the effectiveness of Card-Based Interfaces over Button-based UI and helped define the Game User Interface for the final prototype.

In the character development part, a comparative method was used to analyze three Massively Multiplayer Online games to establish a character design direction according to the proposed framework and with the target audience for the main research user tests. This study also used an exploratory research to find more information about Brazilian ethnics groups as to define a proper set of characteristics for the avatar in the final prototype. The chosen direction followed the stylized design characters of human race and mage class.

Finally, the game prototype was developed based on a series of design needs and requirements constructed upon a set of heuristics evaluations with basis on the ARCS-REACT proposed model. In order to evaluate the prototype in comparison with other educational games and under the ARCS-

REACT categories, a quantitative-qualitative survey was conducted with 60 Brazilian game players to confirm the link between the theoretical framework and final prototype. At this point ten edugames were compared with non-educational ones and a brief overview of the edugames market was also presented.

6.2. Conclusions

This research was based on the problem of education in developing countries, specifically elementary Mathematics. In order to propose a possible solution, the following research question was formulated:

- *Can a Digital Game-Based Learning system based on Contextual Teaching and Learning and Instructional Design help elementary students to learn Mathematics?*

To test this research question, two alternative hypotheses were evaluated:

Table 26 Main Research Hypotheses

HYPOTHESIS	TRUE
Elementary students who will play the proposed game prototype will show a better performance on Mathematics exams than those who won't.	O
Elementary students performance will be related to the game prototype.	O

The research question has guided this entire work, providing directions for all the supplementary studies developed on the way. All these additional work were done with this research question as goal and now they all converge to it. In the chapter 5 this main investigative question was tested against a series of hypothesis that can endorse or not the above alternatives.

First of all, the experiment demonstrated that the Instructional Contextual Learning-Based Game (ICLG) was effective in the students' learning. The treatment group not only has beaten the control group posttest scores, but also performed better in the game. This result confirms our first

alternative hypothesis, since the applied posttest was the very Mathematics exam for both groups.

Secondly, it was tested whether or not the game results were related to the performance demonstrated in the posttest. The results, based on a correlation, returned a strong relationship between game scores and the Mathematics exam score. Hence, the second alternative hypothesis is confirmed.

A third hypothesis was raised during the tests, regarding the relation between the students' performance and the time played. This hypothesis stated that players' score was due to repetition. The correlation tests between scores and playtime, however, has established a weak relationship between them, refusing this hypothesis.

With all this information in hands, we can finally conclude that an Instructional Contextual Learning-Based Game can help improve children's education, specially in developing countries as these games can be developed with cognitive principles in mind, as the ARCS-REACT model proposed.

The ARCS-REACT model proved to be a good guideline for game development with focus on educational content. It was very helpful on defining design directions and development decision making. The defined heuristics were important orientation during the prototyping due to the complexity and multidisciplinary of the game development process.

The player's test about the educational games also returned good results. It was found that story, gameplay and graphics were considered the most important factors in video game attractiveness. Moreover, players have an idea of educational games as poor developed software that lacks visual quality. They rather play a commercial game with better graphics, gameplay and storyline. With better quality educational games, this mindset can be changed and more children maybe starts to look for educational games more often.

Another useful and important result for the development process was the design workflow created. It helped prototype the game quickly and at a low cost. It may help others researchers in need of fast prototyping method or just developers seeking funding.

The *Trading Card Games* and *Card-Based Games* analysis was a fundamental piece to complete the complex puzzle of this research. It helped beyond measure the prototype design by determining the best approach to Game User Interface. Card-based UI promoted a better, faster and intuitive gameplay what resulted in greater game scores and information absorption. Button UI proved to be less clear and complicated to use, even though it is the most common interface in MMOG and most players were advanced game users.

By comparing and investigating three popular MMOG, the character design for the final game prototype was better achieved. It resulted in the used avatar feature as skin color, hair style, hair, color, eye style, eye color, face and clothes. The design followed the *anime* style art and colorful costumes and was based also in Brazil's ethnics groups and culture.

The main objective in this research was to propose a conceptual model for educational games design and the ARCS-REACT is this model. It was theoretically constructed, applied and evaluated with positive results. We can conclude that the research's main goal was reached, although the model still needs future improvements. Also, the ARCS-REACT can contribute to better design educational games and change players' idea about its quality. If players start to perceive educational games as they think about the non-educational ones, the market share for Learning-based games can grow even faster, promoting education and socialization all around the world.

6.3. Future Works

Although this research was not intended to test whether each of the ARCS-REACT parameters would impact on children's learning, the positive results show that it can be tested in future works. There's always room for improvement and this model is a very special case in need of further researches.

The game prototype can be improved as well. With an enhanced mechanics and more levels, the game can be tested with different users, in different schools and countries. The difference between public school and

private school students, for instance can return interesting data for additional analysis and conclusions.

Another aspect that can be much better addressed is the social element of the Contextual Teaching and Learning. In this work, a website and Facebook page were integrated with the game to promote socialization, but the ideal scenario would be a completely functional MMOG. This was, in fact, the original goal of this research, but the complexity of a MMOG design and development has forced the parameters to a simpler game. Player's interaction in a massive educational environment could be better for learning in context and to experiment the Instructional Design models.

AKNOWLEDGEMENTS

I would like to thank the Mathematics teachers José Silva and Telmara Modesto for their incredible assistance with user tests and game prototyping. Also, I thank very much the pedagogue Lenimar Cardoso, who facilitated all the users tests in the SESI School and provided all information needed to complete the research. I'd like to thank Luciana Frazão for all the support and user tests' pictures. A very special thanks goes to fellow Brazilian designers Victor Maxwell, Willen Athayde, Igor Zago and Emanuel Braga for the help with the prototype development. I would like to thank my dear friends, Dr. Anak Agung Gede Dharma and Dr. Michael Brandse for all the help with the research design and statistics approaches. Likewise, I would like to thank my Japanese friend Hiroyuki Kajihara, who helped me beyond count with all university protocols and formalities. I'd like to thank the Kyushu University staff, specially from the International Students and Research Support Center, who always facilitated my life on campus. And finally, a very special thanks to Professor Dr. Kiyoshi Tomimatsu, who accepted me in his laboratory and gave the opportunity to study in Kyushu University.

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APPENDIX A: GAME QUALITY QUESTIONNAIRE SHEET

Jogos Educacionais e Comerciais

O que você acha mais atrativo em um game? *

- Gráficos e Efeitos Visuais
- Jogabilidade
- Trilha e Efeitos Sonoros
- Roteiro
- Sociabilidade

O que você acha da qualidade dos jogos educacionais? *

Observe as imagens abaixo:





Qual dos jogos acima lhe atrai mais a jogar? *

- Jogo A
- Jogo B

Por quê? *

Qual a sua idade? *

Qual a sua escolaridade? *

Enviar

Sylker Teles - Kyushu University

APPENDIX B: USER TEST DATABASE TABLES

Server: custsql-dom08.eigbox.net ▸ Database: db1146565_matemagosa ▸ Table: UserList

UserList

Field	Type	Null	Default	
ID	int(11)	No		
Pass	varchar(32)	No		
FirstName	mediumtext	No		
MidName	mediumtext	No		
LastName	mediumtext	No		
Age	int(2)	No		
Gender	enum('M', 'F')	No	M	
Level	float	No		

Indexes:

Keyname	Type	Cardinality	Field
PRIMARY	PRIMARY	20	ID

Space usage:

Type	Usage	
Data	1,588	Bytes
Index	2,048	Bytes
Total	3,636	Bytes

Row Statistics:

Statements	Value
Format	dynamic
Rows	20
Row length ø	79
Row size ø	182 Bytes
Next Autoindex	65
Creation	Oct 01, 2014 at 03:14 AM
Last update	Jan 06, 2015 at 07:59 AM
Last check	Mar 02, 2015 at 12:00 PM

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Server: custsql-dom08.eigbox.net ▸ Database: db1146565_matemagosa ▸ Table: Sessions

Sessions

Field	Type	Null	Default	
ID	int(11)	No		
Time	datetime	No		
Name	text	No		
Playtime	time	No		
Score	int(11)	No		

Indexes:

Keyname	Type	Cardinality	Field
PRIMARY	PRIMARY	3000	ID

Space usage:

Type	Usage	
Data	123,600	Bytes
Index	32,768	Bytes
Total	156,368	Bytes

Row Statistics:

Statements	Value
Format	dynamic
Rows	3,000
Row length ø	41
Row size ø	52 Bytes
Next Autoindex	3,001
Creation	Oct 01, 2014 at 10:05 AM
Last update	Feb 28, 2015 at 04:02 AM
Last check	Mar 21, 2015 at 12:03 PM

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