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Master of Mathematics Education and Methodology in Mathematics Education

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Video Games in Mathematics Education: The Case of Number Navigation

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Abstract

In this thesis i am dwelling on the subject of video games in education, examining specifically the case of Number Navigation and conducting a semi-experimental research. In the Preface, i am starting with a history review, continuing with a description of the main characteristics of this new era in education, a brief literature review, the constitutional parts of a good video game and some classifications about games and players. The presentation of the game that is being used in this study (Number Navigation) follows up and after that the Methodology where the design of the empirical part of this research is extensively presented. Next the results of this thesis are presented; first the quantitative results of the pre/post tests followed by the qualitative analysis of the open-ended questionnaires. In the last chapter i am presenting a critique of the game and some references for the future of game education. Last but not least i carry on exhibiting in the Appendices Gee's Learning Principles, the expanded results and research tools and finally some of the educational video games that i have dealt with in this study's framework.

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This book is dedicated to my mother and my grandmother for always being there for me.

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Contents

1 Preface - Why Try Games in Education? 1

1.1 Games in Education . . . 1
1.2 A Challenge For Education . . . 2
1.2.1 About Learning . . . 4
1.2.2 The role of teachers . . . 4
1.2.3 Fun in the Learning Process . . . 5
1.2.4 Today's school System . . . 6
1.2.5 Math Education . . . 6
1.3 Brief History of Education . . . 7
1.4 Games and their categorization . . . 8
1.4.1 Constitutional Characteristics of Games . . . 8
1.4.2 Intrinsic and extrinsic motivation in games . . . 9
1.5 Player Classification . . . 10
1.6 Prerequisites of Good Educational Video Games . . . 11
1.6.1 Good Math Video Games . . . 15
1.7 Research Results, Virtues and Shortcomings of Educational Video-Games . 17
1.7.1 Research Results . . . 17

2 The Number Navigation Video Game 23

2.1 Educational goal of the NN game: The development of mental calculation ability . . . 23
2.2 Interface . . . 25
2.3 Game Mechanics . . . 28
2.3.1 Moves Scoring Mode . . . 29
2.3.2 Energy Scoring Mode . . . 30
2.3.3 Game Features . . . 31
2.3.4 Customization . . . 32
2.4 Classification of NNG . . . 33

3 Methodology 34

3.1 Aims of the Study . . . 34
3.2 Pilot study and "Customization" . . . 34
3.3 Participants and Demographics of the Sample . . . 35
3.4 Design & Procedure . . . 35
3.4.1 Data collection . . . 36
3.5 Research Design . . . 38
3.5.1 Pre/Post Tests . . . 38
3.5.2 Demographics Questionnaire . . . 40

3.5.3 Open-ended Questionnaire 41
3.5.4 Gaming Sessions 41

4 Results & Discussion I - Quantitative 43
4.0.5 Demographics Coding and Results 43
4.1 Pre/Post Test Analysis and Results 43
4.1.1 Results 49
4.2 Gaming Sessions Results 52

5 Results & Discussion II - Qualitative 56
5.1 Open-ended Questionnaire Analysis 56

6 Concluding Remarks 84

7 Appendix A Gee's Learning Principles 88

8 Appendix B1 Pre and Post Test Data 93

9 Appendix B2 Quantitative Results 100

10 Appendix B3 Research Design 103

11 Appendix C Games 118

12 Appendix D Participants Screenshots 138
. 148

List of Figures

1.1 Education Today 3
1.2 Tennis for Two 8
1.3 Bartle's Taxonomy 10

2.1 Screenshot of the Directory File of NNG, the red-circled file is the executable file of NNG 25
2.2 Screenshot of the Main Screen of NNG 26
2.3 Initial Level, First Level, Second Level and Third Level 27
2.4 Sample Stage Picture in Moves Mode 28
2.5 Sample Stage Picture in Energy Mode 29
2.6 (a) Ship's movement animation (b) Ship is blocked by an island 30
2.7 Pirate and Hitting Upon the Pirate 31
2.8 Arithmetic Operations of Addition and Subtraction Are Hidden 32
2.9 Txt File For Stage Modification 33

3.1 Summary of the Study Image 36
3.2 Typical Open Problem From the Pretest Questionnaire 38
3.3 Sample Constrained Problem From the Pretest Questionnaire 39
3.4 Sample Multiple-choice Equation Problem From the Pretest Questionnaire 39
3.5 Sample Fill-in equation Problem From the Pretest Questionnaire 40
3.6 Sample Fill-in equation Problem From the Pretest Questionnaire 40
3.7 Initial Starting Screen and Second Level Starting Screen of NNG 42

4.1 Gender 44
4.2 Age 44
4.3 Education Degree 44
4.4 Gender 45
4.5 PC Use 45
4.6 Video-Games Use 45
4.7 Educational Practice 46
4.8 Mean Scores of The Comprising Parts of Pre & Post Tests 51
4.9 Mean Scores of The Comprising Parts of Open Items 51
4.10 Mean Scores of Medal Performance 52
4.11 Mean Scores of Gaming Quality Indexes 53
4.12 Preference of Gaming Mode 54
4.13 Mean Scores of Mode Preference 55

5.1 Reflection About Skill in Mental Calculations 57
5.2 Importance of Mental Calculations in Mathematics Education 58

5.3 Teaching Toward Mental Calculations . . . 59
5.4 Promotion of Mental Calculations Through NNG . . . 60
5.5 Video Game Experience . . . 61
5.6 Video Games in the Classroom . . . 62
5.7 Thesis Towards Video Game Implementation . . . 63
5.8 To Enjoy or Not the Educational Video Games . . . 65
5.9 Does VGs Implementation Suits Best to a Specific Course? . . . 67
5.10 Beliefs About Genre Differences . . . 68
5.11 Thesis Toward NNG . . . 68
5.12 Negative Emotions During Gameplay . . . 71
5.13 Would you be motivated to play the game in your own time? . . . 72
5.14 Will the In-Game Goals Be Motivating Enough For Students? . . . 73
5.15 Easiness of Concentration During Gaming Sessions . . . 74
5.16 After how long did the game tire you, if it did? . . . 75
5.17 Attractiveness of NNG . . . 76
5.18 How would you Use NNG . . . 77
5.19 Difficulty of the Number Navigation Game . . . 78
5.20 Engaging/Fun Features Of NNG . . . 79
5.21 Would you play NN in order to complete it? . . . 82

8.1 Demographics . . . 94
8.2 Pre Test Open Problems . . . 94
8.3 Pre Test Constrained Problems . . . 95
8.4 Pre Test Multiple Problems . . . 96
8.5 Post Test Open Problems . . . 97
8.6 Post Test Constrained Problems . . . 97
8.7 Post Test Multiple Choice Problems . . . 98
8.8 Game Sessions Results . . . 99
8.9 Game Mode Preference Analytic Data . . . 99

9.1 Descriptive Statistics and Pearson Correlation for PreTotalAdapted and PostTotalAdapted Scores . . . 101
9.2 Kendall's Tau and Spearman's Rho Correlation for PreTotalAdapted and PostTotalAdapted Scores . . . 101
9.3 Wilcoxon Matched Pairs Sign Ranked Test . . . 102

10.1 PreTest Page 1 . . . 104
10.2 PreTest Page 2 . . . 105
10.3 PreTest Page 3 . . . 106
10.4 PreTest Page 4 . . . 107
10.5 PreTest Page 5 . . . 108
10.6 PreTest Page 6 . . . 109
10.7 PostTest Page 1 . . . 110
10.8 PostTest Page 2 . . . 111
10.9 PostTest Page 3 . . . 112
10.10 PostTest Page 4 . . . 113
10.11 PostTest Page 5 . . . 114
10.12 PostTest Page 6 . . . 115
10.13 Digital Open-ended Questionnaire . . . 116

10.14Demographic Questionnaire 117

11.1 AquaMOOS 3D 119
11.2 Different Stages of Zoombinis 119
11.3 Restaurant Empire 120
11.4 GeoChallenge 120
11.5 Crayon Physics 121
11.6 DimensionM 121
11.7 Ko's Journey 122
11.8 NIU-Torcs 123
11.9 Lemonade Tycoon 123
11.10Civilization III 124
11.11La Jungla de Optica 125
11.12Quest Atlantis 126
11.13SimSchool 126
11.14Logo 127
11.15Lemon Stand 127
11.16Snooper Trooper 128
11.17Oregon Trail 128
11.18Carmen Sandiago 129
11.19Odell Lake 129
11.20Reader Rabbit 130
11.21Number Munchers 130
11.22Loom 131
11.23Lemmings 131
11.24Kodu 132
11.25Calculation Nation 132
11.26Timez Attack 133
11.27Portal 133
11.28KickBox 134
11.29Wuzzit 135
11.30Motionmath 135
11.31Refraction 136
11.32Dragonbox 136
11.332048 137

12.1 Participant No1 139
12.2 Participant No2 139
12.3 Participant No3 140
12.4 Participant No4 140
12.5 Participant No5 141
12.6 Participant No6 141
12.7 Participant No7 142
12.8 Participant No8 142
12.9 Participant No9 143
12.10Participant No10 143
12.11Participant No11 144
12.12Participant No12 144
12.13Participant No13 145

12.14Participant No14 145
12.15Participant No15 146
12.16Participant No16 146
12.17Pilot Participant 147

1

Preface - Why Try Games in Education?

If the children don't learn the way we teach maybe we should teach they way they learn!

– Anonymous participant of EYE 2014 Conference in Strassburg

1.1 Games in Education

Games in education is not a new idea; from the animals where the mother teaches her offspring the essential skills for its survival through play, to humans; play is written in our dna[32]. Consider the Stomachion (similar to Tangram) in Ancient Greece which consisted of a geometric problem [61] and Kriegsspiel (literally war play) which was a system used for training military officers in the Prussian army by Helwig in 1780 AD [18, 61]. Games follow us throughout the course of our brief history on earth and they are an essential part of our lives from our early years to our last ones!

Vygotsky argued that play contains a fundamental social aspect needed for cognition in his research, constructing the social learning theory and he also indicated that game play withholds an enormous potential to influence children[60].

The paradox of play is that we are willing to do difficult even frustrating work because we are having fun and this is the true power of gamification[34]

Games create intrinsic motivation through fantasy, control, challenge, curiosity and competition (Malone 1981, Cordova and Lepper 1996)[56]. Games in classroom and play in general, can leverage players' desires to develop new skills, participate in new roles, or better understand the world from a new perspective (Gee 2005; Shaffer 2004-5; Piaget; Vygotsky)[56].

According to Vygotsky [36] play, like all functions of consciousness, originally arises from action and must always be interpreted as the imaginary, illusory realization of unrealizable desires. Vygotsky explains that it is not the case that play occurs only as the result of each and every unsatisfied desire. For instance, it is not the case that the child wants to take ride in a cab, but as its wish is not gratified goes into his room to play "cabs".

In play the child is free, yet this freedom is "constrained". Every imaginary situation will always contain rules; these rules are accepted by the child and get internalized. They

become his own rules. Piaget [36] calls them "rules of self-restraint and self determination". The child tells to himself: I must behave in such a way in this game.

This conformity to the rules occurs because, for an individual to observe the rules and the structure of the play promises much greater pleasure from the game than the gratification of an immediate impulse. As Vygotsky frames it quoting Spinoza: "An affect can only be overcome by a stronger affect". Nohl showed that a child's greatest self-control occurs in play![36]

Play entails more recollection than imagination - that is, it is more memory in action than a novel imaginary situation[36]. In some way our imagination is formed by our memories, by the things we have lived.

Play is a purposeful activity for a child and purpose as the ultimate goal determines the child's affective attitude to play. Simply running around without purpose or rules of play is a dull game that does not appeal to children[36].

1.2 A Challenge For Education

National Teachers Union claims that as far back as 1988 only $20 - 25\%$ of students could learn effectively from traditional methods of teaching[45]. Students' common complaint is that every time they go to school they have to power down. We have reached the point where many students who succeed in school, they do it in spite of the formal education system and not because of it[45].

There is a new generation of computer literate students who demand quick and more frequent interactions and inductive reasoning, pupils using different information at the same time, generations that quickly acquire the rules of a computer game and solve problems using computers[11].

Quoting Prensky from [45]:

> The students who have grown up in the last 25 years have had an extraordinary, never-before-seen set of formative experiences: Each day the average American teenager watches over 3 hours of television, is on the Internet $1^{1/2}$ and plays $1^{1/2}$ hours of video games. By the time these people graduate they will have, with conservative estimations, an average of close to 10,000 hours playing video-games, over 200,000 emails and instant messages sent and received, close to 10,000 hours of talking, playing games and using data on digital mobile phones, over 20,000 hours of watching TV, almost 500,000 commercials seen all of these adding up to tens of millions of images. And maybe, at the very most, 5,000 hours of book reading.

These "Digital Natives" as Prensky calls them, in contrast to the "Digital Immigrants" (the older ones, people "under 36" who arrived at the "digital shores" later in life), are a generation that, for the first time in history, grew up deeply experiencing a radical new form of play (i.e. video games). Those Natives are bound to have a distinct way of perceiving the world and getting knowledge because their brains are trained to react different when receiving specific stimulae (i.e. images, videos etc).

Our Brain is a living, breathing organism which is directly affected by what we are "feeding" him. Different kinds of experiences lead to different brain structures [45]. It constantly reorganizes itself in all our child and adult lives, a phenomenon known as neuroplasticity. Such examples of neuroplasticity stem, for instance, from neuro-imaging experiments with blind adults showing that when they learned Braille, "visual" areas of

Figure 1.1: Education Today

their brains lit up [45]. Moreover, deaf people use their auditory cortex to read sings. In other words, our brain is created from the input it gets.

Of course the way Digital Natives perceive the world and get knowledge is not fundamentally different than that of the older generation but it differs enough to require a modification in the education process in order to prepare this new generation to face the ever-changing world.

Prensky declares that this discontinuity in education is starting to become visible with the naked eye and in fact our whole learning system, which worked for hundreds of years, is breaking down. Until now we have been working hard to educate a new generation in the old ways, using tools that have ceased to be effective[45]. Any teacher who thinks that we can change things and win the students back with the "old ways" is fighting, as prensky states, a losing battle. He reports that this video game implementation is the third time in human history that a "brain reprogramming" has happened. The first one had to do with the need to deal with the difficulties of the environment (i.e. construction of tools artifacts etc) and the second one when we had to deal with the invention of written language and reading[45].

Prensky predicts that as the demand for intrinsically motivating learning becomes more critical; and as academic instructors and institutions are eventually get forced to confront the fact that the generations who love to play video-games are also their students, the learning process stands at the beginning of a huge revolution[44]. But every new technology necessitates a new war (for the new order to be established)[45].

Prensky professes and argues that within most of our lifetimes pretty much all learning will become truly learner-centered and **fun**; as he quotes being overly optimistic: "fun for the students, fun for the trainers and teachers, fun for the parents, supervisors, ad-

ministrators and executives". This will not only make learning and training much more enjoyable and compelling, but far more effective as well[45]. This is because learners will demand it, to the point that teachers and administrators can no longer resist[44].

Although Presky's views have been criticized of being over-simplistic and too optimistic about the value of digital games for learning [9], there is no doubt that searching for appropriate ways to engage Digital Natives in learning poses a challenge for education. Moreover, it appears that Digital Game-Based Learning (henceforth DGBL) is something more than just a radical idea. It has actually emerged in various learning situations [45]:

- Pre-schoolers learn the alphabet and reading through computer games
- Elementary students learn the K-6 curriculum on Playstations; scores rise 30-40%
- Computer chess becomes a big part of K-12 curriculums
- Typing games are among the top-selling software products
- High schools students play a multi-player online game to learn electoral politics
- Financial traders use computer games to hone their skills
- Policy makers play a Sim City-style game to understand the health care system
- Engineers use a consumer-style videogame to learn new CAD technology
- Military trainees fight realistic battles in videogame-like simulators

1.2.1 About Learning

A large part of the educational discourse in our schools is on what to teach - aka the curriculum - rather than on how students learn it[45]. Views on learning have changed radically from the time learning was viewed as the ability to recall information. Defining what learning is a very challenging task. Characteristically Prensky cites that in the education profession asking "how do people learn" is a lot like asking "What is the true religion". Every religious person is convinced that his faith is the true one and yet there are literally thousands of different religions in the world. The truth is that learning is a complex phenomenon with a huge number of variables. In fact we learn different things with different procedures[45].

While there is no consensus on how exactly people learn, almost all theories: recognize that a key feature in the learning process is to engage the learner[45] and emphasize the importance of motivation in any learning process (Bixler 2006).

New interactive technologies provide opportunities to create learning environments that actively involve students in the learning process [60]. Moreover, learning in such contexts may be fun - as great teachers have known throughout the ages, learning does not feel like work when you 're having fun - the term that is being used for this kind of learning is "hard fun"[45].

1.2.2 The role of teachers

The suggestion of grounding learning on digital games raises important questions about the role of teachers. People who advocate this idea argue that the use of video games

in the classroom will be complementary and that video games are not here to reduce teaching personnel or to replace academic stuff.

On the other hand, educators hoping that digital games will be a "silver bullet" or the "Royal road" because they are exciting and motivating will be disappointed[56].

Thus, Teachers will do what good teachers have always done: probe, encourage discussion, point out important meanings, make the connections and so on[45]. "I never try to teach my students anything" said Albert Einstein in one of his famous quotes "only try to create an environment in which they can learn". That is the way that EVG should be used in education, i.e. in an "instrumental", as Devlin eloquently suggests, way:

> The games in education are not designed to teach. The intention is to provide an "instrument" that, in addition to being fun to play, not only provides implicit learning but may also be used as a basis for formal learning in a scholastic setting[16].

1.2.3 Fun in the Learning Process

The answer to the question - does school and training have to be boring - is an emphatic and absolute no!

There are a lot - maybe all of us in some grade - of believers of Benjamin Franklin's aphorism: "Things which hurt, instruct"[44] or in the "No pain no gain" saying.

And this is right. Pain does instruct. Undoubtedly when you touch a naked wire and get electrified you learn the harmful part of electricity but is this the only way to learn about this? Is pain the only way to instruct somebody? Is it a necessary part of the learning process? Or is it just a way? Of course pain is just a way to instruct somebody and may i say not the best one. There are other ways to learn new things.

Prensky remarks in [44] that:

> There is a strong religious tradition involved in this subject. How happy Adam and Eve were before they ate the fruit of which tree? In the extreme biblical view, knowledge is the cause of all man's suffering. All learning is painful, knowledge is sin, and thus learning is merely a form of suffering. For thousands of years the church controlled schools and learning. Many of its precepts still live on in the minds of educators. Although religious thought has many positive things to offer us, the links between knowledge and evil, fun and sin are not among them. It is certainly time to throw out these "learning shackles" as well.

Proponents of "fun learning" relate fun to enjoyment and pleasure. Opponents relate fun to amusement and ridicule. They use the same word but don't speak the same language[44].

But for now it can be accurately claimed that the meaning of "learning" is sufficiently unclear that it is not possible to exclude "fun", (in the sense of enjoyment) from the process[44].

"In simple terms a brain enjoying itself is functioning more efficiently...When we enjoy learning, we learn better" (Rose and Nicholl 1998)[44].

The role that fun plays with regard to intrinsic motivation in education is twofold. First, intrinsic motivation promotes the desire for recurrence of the experience and secondly, fun can motivate learners to engage themselves in activities with which they have little or no previous experience" (Bisson & Luckner 1996)[44].

1.2.4 Today's school System

Nowadays we are witnessing a mad rush to pour educational content into games in an ad hoc manner in hopes that players/learners are motivated simply because the content is housed inside a game as Offenholley states[32].

Prensky cites in his book [45] Seymour Papert's (MIT professor) adage: The reason most kids don't like school is not that the work is too hard, but that it is utterly boring.

To lure someone into coming to the learning process might be easy but to make him stay focused and to keep his interests high is a very hard task. Prensky quotes a writer in a Training magazine who said: the thing that keeps him awake at night is how to get people to finish the online training.

In most developed countries education has been penetrated by Information Technology (IT) and specifically with this growth of the computer technology, software use has been able to redefine and simulate mathematical concepts (Keibritchi, Hirumi & Bai 2010) as cited in [48].

1.2.5 Math Education

For over 2000 years, the only way to provide mathematics education to everyone was through the written words - textbooks[15]. Mathematicians drew their mathematical symbols first in the sand, then on parchment and slate, and still later on paper and blackboards. Video games provide an entirely different representational medium. Their dynamic environment make them far better suited in many ways to representing and doing middle-school mathematics than using symbolic expressions on a page. We need to get beyond thinking of video games as an environment that delivers traditional pedagogy a new canvas on which to pour symbols and see them as an entirely new medium to represent mathematics[15]. Now this new medium for delivering education is here and knocks our door.

Math is not just about the knowledge of the algorithmic procedures and in general about the factual knowledge, it's something you do. Textbooks can be a terribly inefficient way to learn how to do something. The best way for an individual to learn how to do something is, as the Nike slogan says: "Just do it!"[15].

Doing math is something that takes place primarily in your head. Symbols are just a representation for and a supportive tool to your math-thinking. In fact people can become highly skilled at doing mental math and yet be hopeless at its symbolic representation.

So why do we still bother teaching symbolic math? There are some excellent reasons which Devlin cites in [15]: One is that it is essential for modern life that there are enough people around who are really good at symbolic math. Science and engineering depend heavily on symbolic math. A second is that it is a key gateway to more advanced mathematics and a lot of other subjects as well.

You are a different person after you complete a course than you were beforehand. Taking the course has transformed you, and you see life differently. But the transformation is a result not of your having learned some new facts, but because you have learned to look at the world differently and to think a different way[15]. That is what education is about and not acquisition of factual knowledge and mechanical skill[15].

Every citizen of today's world must have achieved a degree of mastery in this set of abilities to which Devlin refers as *everyday mathematics*. Everyday mathematics includes the following topics: *i*) basic number concepts,*ii*) elementary arithmetic,*iii*) arithmetical relationships,*iv*) multiplicative, *v*) proportional reasoning,*vi*) numerical estima-

tion,*vii*) elementary plane geometry,*viii*) basic coordinate geometry,*ix*) elementary school algebra,*x*) quantitative reasoning,*xi*) basic probability, *xii*) statistical thinking,*xiii*) logical thinking,*xiv*) algorithm use,*xv*) problem formation (modeling),*xvi*) problem solving,*xvii*) and sound calculator use[15].

1.3 Brief History of Education

> Originally education and training was a process of imitation and coaching - in way as the popular adage says "monkey see monkey do".
>
> To make this repetitive skill-based learning both bearable and memorable, practicing became, even in animals, a form of play. This apprenticeship type of learning - demonstration and practice - requires good coaches and typically a one-to-one relationship. It is how even today people learn to do sports, play musical instruments and master other physical skills.
>
> The next addition to this learning process was pictures and symbols (cave paintings etc). Undoubtedly the following technological innovation in learning was the development of the spoken language. The epic tales of Homer were in meter and rhyme so that people will be able to memorize them more easily. With this spoken language we can ask questions and see if we can answer them in a way that shows our understanding. This so-called dialectical or "Socratic Method" of questioning and trying to elicit a reply is still in use, for example in Law schools.
>
> Subsequent to the development of language was the invention of literacy: writing and reading. While Socrates didn't write down his speeches, Plato did and that is why they have survived until today.
>
> The next big great technological change was the invention of printing press in the West. Now the educational materials could be produced massively and distributed to anyone who want them.
>
> Our modern mass education according to Neil Postman (NYU communication professor) was designed to bring everyone to a basic level of literacy. As he quotes: "school was developed primarily to teach people to read books" and that "school is intended to equip us not only to read, but to think along the lines of books (linear thinking)".
>
> Then came the industrial revolution, which led to both furthur standardization of the school system ("a machine to turn out workers" as Seth Godin [a public speaker and writer] says) and particularly to the need for testing to put people in the correct jobs quickly.[45]

So Prensky is concluding that this tell-test education is in reality merely a tradition of three hundred years and have worked pretty well until the mid 20th century.

Brief History of Video Games in Education

The first video game was called Tennis for Two was launched from the U.S. Brookhaven National Laboratory in 1958 and created by William Higinbotham(see figure 1.2). Educational Video Games (EVG hereafter) or Serious Games (current terminology) come in 1980s for a school implementation for the first time in U.S.A.. The first educational

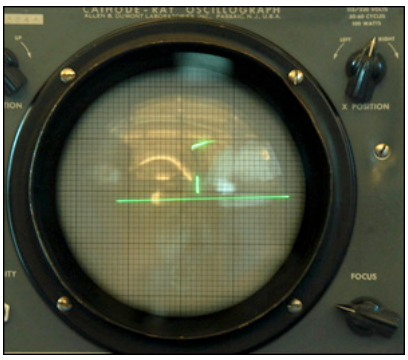


Figure 1.2: Tennis for Two

video-game is considered to by Logo created in 1967 by Seymour Papert, emeritus, now, professor in MIT (see more in the Game Appendix).

Historically, computers have been used in education primarily as tools for supporting drill and practice for factual recall (Jonassen 1988)[57]

Continuing advances in technology, the widespread popularity of entertaining computer games, and recent reports underscoring the potential of game-based learning (Egenfeldt-Nielsen 2005; Federation of American Scientists 2006; Mitchell & Savill-Smith 2004) have renewed interest in the use of instructional games (defined here as computer games designed for training or educational purposes) in various sectors, such as but not limited to health (Papastergiou 2009b), education (Coller & Scott 2009; Ke & Grabowski 2007) and military (Smith 2010).

1.4 Games and their categorization

1.4.1 Constitutional Characteristics of Games

In general according to Prensky (2001) as cited in [53] there are six structural factors that games consist of:

1. **Rules** impose limits and force us to take specific paths to reach goals and ensure that all the players take the same paths or similar ones.

2. **Goals or Objectives** create a sense of duty on us and thus we are "voluntarily obliged" to play the game and make an effort to finish it.

3. **Outcomes and feedback** are the tool to measure your progress in game, your achievement of the goals/objectives etc. Feedback is prompted when something in the game changes in response to what you do.

4. **Conflict, competition, challenge and opposition** are the "problems" you are trying to solve in the game environment.

5. **Interaction** has two important aspects. The first is the interaction of the player and the computer (Players vs Environment (PvE)). The second is inherently social aspect of games that you do with other people (Player vs Player(PvP)).

6. **Representation** which means that the game is about something meaningful.

1.4.2 Intrinsic and extrinsic motivation in games

Intrinsic and Extrinsic Goals

According to positive psychologist Tim Kasser [17], *intrinsic goals* "are those that are inherently satisfying to pursue because they are likely to satisfy innate psychological needs for autonomy, relatedness, competence and growth"; they depend on satisfying one's own basic psychological needs rather than relying upon the judgments or approval of others. Examples of these goals include self-acceptance, forming social connections and physical fitness.

Extrinsic goals, on the other hand, are focused on attaining rewards and/or praise from others–they are a means to an end, not inherently rewarding in and of themselves. Examples include financial wealth, fame, or popularity[17].

People often pursue extrinsic goals under the assumption that these goals will bring them happiness, but evidence suggests otherwise. Researchers speculate that intrinsic goals lead to greater happiness because, in the pursuit of these goals, people have positive experiences along the way that support their happiness.

Intrinsic and extrinsic motivation in psychology have to do with whether a person is motivated internally, or by external rewards. Malone and Lepper (1987) use this concept to describe the structure of a game. In an intrinsic game, the concepts being learned are an integral part of the game, this means that we cannot swap out the content and teach something entirely different with the game. As Herz puts it: "Games are played for the intrinsic reward of playing them, for the emotional state they produce (Herz 1997)"[57]. In an extrinsic game, different concepts can be taught in the same game structure without changing the game[47, 32]. Schools are structured around extrinsic rewards, such as good grades or a fear of failure (flunking)[57].

An example of an intrinsically motivated game is Ko's Journey, as Offenholley remarks the particular mathematics of ration and proportion and angles is an integral part of the game and we cannot swap out this content for different content, without having to alter the game[47]. It could be argued, corresponding to the definition of intrinsic goals, that in Ko's Journey can satisfy the player's innate need for competence and growth. Such games create a sense of purpose (one invests time and accomplishes something, even if it has no true value for his mental, physical, or social state). Maybe it is connected with people's need for mastery of a subject as Boekaerts suggests[41].

An example of an extrinsically motivated game is DimensionM whose target is drill and practice exercise. It could be argued, corresponding to the definition of extrinsic goals, that DimensionM is focused on attaining rewards which are the end in themselves, of course you have the greater target to move through the level but this goal is not connected to the task at hand disrupting the "flow" of the game by getting the player out of the actual game environment in order to make calculations.

Offenholley states that we can conjecture that Ko's Journey may help students get better at using mathematics to solve problems, while Dimension M. may help students get better at taking standardized tests without improving general problem solving skills[47].

Another classification that Offenholley proposes for math video games is the Epistemic Games where the player becomes a mathematician and problem solver within the context of the game. Identity in Games (see Game identity in the section of Prerequisites of Good Educational Video Games) is key to learning well[47]. An example of such a game according to [47] is NIU-Torcs, a simulation game created specifically for college mathematics education. Brianno Coller and colleagues developed the game to help their

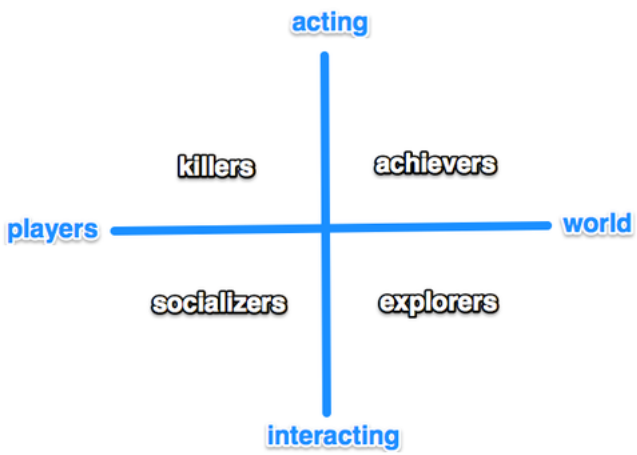


Figure 1.3: Bartle's Taxonomy

mechanical engineering students learn numerical methods (Coller & Scott 2009)[47].

Furthermore a classification that concerns specific subject video game, e.g. math educational video games, is about their content integration. Thus there are integrated or non-integrated in a specific content games. This categorization concerns the math content of the video game and its integration in the game i.e. how the mathematical content blend into the game. To clear this out with an example: DimensionM is an example of a non-integrated game as the math content "pops-up" disrupting the flow of the gameplay while Soduku is a clear mathematically integrated game as the math content cannot be substituted.

Last but not least Kappers states that there is a clear distinction between commercial video games and educational video games whose primary difference according to Van Eck (2006) falls into the realm of entertainment versus education[60]. This distinction is of course somewhat nominal and is not supported by specific literature.

1.5 Player Classification

Richard Bartle's taxonomy is surely an old one but is still a paragon for player categorization. He identified four different kinds of online fantasy game player as Devlin quotes:

- problem solvers-players who seek to succeed in specific tasks within the game;
- explorers-players who gain the most enjoyment from discovering as much as possible about the game world;
- socializers-players whose primary interest is socializing with other players; and
- competitors-players whose main goal is to compete with and attain power over other players.

Bartle's taxonomy, while imprecise, is well known within the game developer community (see figure 1.3).

There is also a list of the characteristics exhibited by video games and their regular players made by Beck and Wade, as Devlin cites[15]:

1. failure doesn't hurt

   Many students give up on math because they can't stand failure

2. risk is part of the game

   To learn you have to be prepared to fail. And you will fail. Repeatedly!

3. feedback needs to be immediate

4. trial and error is almost always the best plan

5. there's always an answer

   Didactical Contract

6. I can figure it out

7. competition is fun and familiar,

   some students are unwilling to "win" at competition because they do not want to stand out in the competition and be ostracized by their peers.

8. bosses and rules are less important

1.6 Prerequisites of Good Educational Video Games

In the present section we will check what are, according to current research in the field, the necessary conditions for an educational video game to be good.

Flow state

People play games because the process of game playing is engaging. This engagement as Prensky puts is very close to that magical state of motivation some refer to as "flow"[44].

Csikszentmihalyi (1990) describes flow as a state of optimal experience, whereby a person is so engaged and intensely concentrated in the activity that self-consciousness disappears, time becomes distorted and people engage in complex, goal-directed activity not for external rewards, but for simply the exhilaration and excitement of the activity [57, 60, 20].

Bowman contrasts video gamers, who are engaged in states of flow, with students in traditional school environments. Students in traditional, teacher led classes have little control over what they learn, are passive recipients of material chosen by teachers, must conform to the pace and ability level of the group (group instruction) and are given shallow, imprecise, normative feedback on their work[57].

This flow state is an inherent characteristic of video games, maybe you can get in flow state watching a great movie or perhaps a terrific book (Gee disagrees citing that book and movies, for all their virtues cannot achieve this flow state[20]) but in video games it is easier to achieve this state and i believe that this has to do with play and the way that it is bound to our nature and existence. So if we want to grasp the full potential of video games we must find a way to implement this flow state in educational video games.

Game identity

Taking on the identity of a learner in order to encourage deeper learning is also a key concept in Gee's groundbreaking book[20] as it is quoted by Offenholley[32]. Devlin explains it better "doing mathematics means thinking like a mathematician - which means not just training in procedural fluency but also in conceptual understanding, strategic competence and more".

According to Devlin we learn by doing the real thing (the task or the skill that we want to master). In fact it is a proven method that goes back to the beginning of human learning. The most adaptive device on the planet, until now at least, is the human brain[16].

Keith Devlin addresses to the subject matter loud and clear saying in [15]:

> It is true for anyone and pretty much any human activity that unless you get inside the activity and identify with it, you are not going to be good at it. If you want to be good at activity X, you have to start to see yourself as an X-er to act like an X-er.
>
> A large part of becoming an X-er is joining a community of other X-ers. It's more an attitude of mind than anything else, though most of us find that it's a lot easier when we team up with others.
>
> Gee uses the term semiotic domain to refer to the culture and way of thinking that goes with a particular practice The crucial part of becoming competent at some activity is to enter the semiotic domain of that activity. This is why we have schools and universities, and this is why distance education will never replace spending a period of months or years in a social community of experts and other learners. At least not until we find a way to make an equally realistic virtual community.

Fun in Games

Fun is a key feature when we refer to good games. A good game is a fun game. Through a series of observations, surveys and interviews, Malone (1981) generated three main elements that "Make video games fun": Challenge, fantasy and curiosity. Malone uses these concepts to outline several guidelines for creating enjoyable education programs. Malone (1981) [57] argues that educational programs should have:

- clear goals that students find meaningful.
- multiple goal structures and scoring to give students feedback on their progress,
- multiple difficulty levels to adjust the game difficulty to learner skill,
- random elements of surprise,
- an emotionally appealing fantasy and metaphor that is related to game skill

Good Goals in the Game

In order for a computer game to be challenging it must provide a goal whose attainment is uncertain[40].

A game is usually boring if the player is either certain to win/lose so the uncertainty of the outcome as Malone presents it in [40] is based on 4 principles:

(a) Variable difficulty level

Good games should allow customization in difficulty level. The choice of difficulty level can be:

- determined automatically by the program according to how well the player does (drill & practice)
- chosen by the player
- determined by the opponent (chess)

(b) Multiple level Goals

Games should be challenging but also do-able, Gee remarks that they should be pleasantly frustrating, which is a very motivating state for human beings[20].

When motivations dies, learning dies and playing stops[20].

Motivation is according to cognitive science is a learner's willingness to make an extended commitment to engage in a new are of learning[20].

Malone considers two levels of goals: the basic goal where you accomplish something in the game world and a meta-goal which is achieved by reaching the basic goal efficiently.

(c) Hidden information

Many games make the outcome uncertain by controlling the flow of information they give to the user and revealing things at the game's pace. This feature according to Malone provokes the curiosity of the user which is essential for the engaging power of the game.

(d) Randomness

Goals and challenges are captivating because they engage the user's self-eseem. Success in a computer game can make people feel better about themselves[40].

Curiosity

Curiosity is the motivation to learn, independent of any goal seeking or fantasy fulfillment. Computer games can evoke a learner's curiosity by providing environments that have an optimal level of informational complexity (Berlyne 1965; Piaget 1952) as cited in Malone[40]

Malone distinguishes two kind of curiosity: Sensory Curiosity and Cognitive Curiosity.

Sensory curiosity involves the attentions attracting value of changes or patterns in the light, sound or other stimuli of an environment. Computer games appeal to sensory curiosity by the use of audio and visual effects.

Cognitive curiosity can be thought of as a desire to bring better "form" to one's knowledge structures. An example that Malone gives is this: "if you have just read all but the last chapter of a murder mystery book, you have a strong cognitive motivation to bring completeness to your knowledge structure by finding out who the murderer was"[40].

Explorative learning, which is based on our inherent curiosity, leads to ownership of what is learned. We appreciate, value and take pride in what we discover for ourselves[15].

As a species, humans are natural born learners. Every one of us. All it takes to stimulate someone to want to learn is interest or curiosity[15]. We humans survived as a species because we evolved to be problem solvers. It's in our genes to solve problems and it gives us enormous pleasure to do so.[15] Thus an educational video game, in order to seize its full potential, should nourish curiosity; that is the player must be intrigued by it.

Feedback

Feedback is another essential tool in the arsenal of good educational video games. Concerning the feedback Malone thinks that it should be informative and a product of a responsive virtual environment. In particular he makes the following two preconditions in order for the feedback to be effective.

1. Feedback should be surprising to engage a learner's curiosity

2. Feedback must be constructive in order for it to be educational. In Malone's words it shouldn't just reveal the learner that his knowledge is incomplete, inconsistent or unparsimonious, but should help him to become complete, consistent and parsimonious.

[40]

Good games give information "on demand" and "just in time", not out of the contexts of actual use or apart from people's purposes and goals, something that happens too often in schools[20].

People are quite poor at understanding and remembering information they have received out of context or too long before they can make use of it (Barsalou 1999; Brown et al 1989; Glenberg and Robertson 1999)[20].

Good games never do this to players, but find ways to put information inside the virtual worlds the players move through and make clear the meaning of such information and how it applies to that world[20].

Stealth Learning

Another characteristic that is considered indispensable in Good Educational Video Games is Stealth Learning. By definition "Stealth Learning" is a term which is used to say that you camouflage the learning process in video games in order for them to be fun.

Most educational gaming researchers recommend learning by stealth, that is learning can only be engaging when it is concealed within games and thus unconscious to the learners, when it is integral to the story of game world, and when it is designed as authentic activities associated with a virtual identity or character (Gee 2003; Prensky 2001)[31].

In experiential learning theory where knowledge is constructed, not transmitted, as a result of experiencing and interacting with the environment, in today's computer games you are part of a living, breathing, simulated universe with which you have to interact in order to learn [43].

This kind of experiential learning (or Situated Learning) has long been known to be extremely effective but to provide such an education without video games it's almost impossible except on a one-on-one basis in some form of apprenticeship or tutoring system[15].

Gameplay

Gameplay is all the doing, thinking and decision making that makes a game either fun, or not. In a puzzle game, the Gameplay is the physical and mental activities in the puzzles. In a shooter, it's the player's and the opponents' speed and abilities. In a strategy game it's the available options and tactics. Gameplay includes the game's rules, the various player choices and how easy, gradual or hard or the road to success is.[44]

One basic rule of good Gameplay, is to always provide the player with clear short-term goals. Another is to make the game easy to learn, but hard to master like Chess[44]. A good game must always balance and adjust itself so that it continually keeps the player in the "Flow Zone".

If the game is designed right the player will be engaged. And it is this continuous challenge/engagement at the precise context-and-user-appropriate level that motivates. Good gameplay requires that every second of the experience be engaging[44].

If a game cannot be learned and even mastered at a certain level, it won't get played by enough people and the company that makes it will go broke. Good learning in games is a capitalist-driven Darwinian process of selection of the fittest in Gee's words[20].

Embracing Failure

Failure in the game, if the student perceives it in the "right" way (here with right i mean that failure is an integral part of the learning procedure), is the beginning of a valuable learning experience. For other students failure causes frustration. Students with confidence saw failure as an opportunity to learn, while others did not. Squire in his implementation of Civilization III reports that failure affronted those students who identified themselves as gamers, suggesting that educational games may not be such an easy win for this population of students - who may be inclined to reject educational games out of hand if such games challenge or compromise their identities as gamers and their status.

Making mistakes is a large part of how players learn. They are, if not the key, an essential part to learning. Gee calls his game principle relevant to failure: "failing forward" (See Appendix B). In school, it is often bad to get a wrong answer, or to fail at a task; in video games, it is expected[47].

We learn a lot from our mistakes and educationally it is extremely effective to be able to repeat an experience where things went wrong and try to get it right the second time[15].

And as most of us know, lessons learned as a result of our "failures" are rarely forgotten. In order for failure to be an effective learning mechanism, the failure has to hurt sufficiently for us not to want to repeat it, but should not be so great that we lose heart and give up[15].

Fortunately video games are a very good, if not the best, environment to achieve an appropriate degree of "hurt" for the students to motivate them but just enough so the player doesn't gives up.

1.6.1 Good Math Video Games

Devlin[16] capitalizes that a good math learning game or app should avoid:

- Confusing mathematics itself (which is really a way of thinking) with its representation (usually in symbols) on a flat, static surface (2D).

- Presenting the mathematical activities as separate from the game action and game mechanics.

- Relegating the mathematics to a secondary activity, when it should be the main focus.

- Adding to the common perception that math is an obstacle that gets in the way of doing more enjoyable activities when doing math should be a end in itself (not means to an end).

- Reinforcing the perception that math is built on arbitrary facts, rules and tricks that have no unified, underlying logic that makes sense.

- Encouraging students to try to answer quickly, without reflection (drill and practice games).

- Contributing to the misunderstanding that math is so intrinsically uninteresting, it has to be sugar-coated.

Finally Devlin theorizes that for a mathematics game to be good, "the math should arise naturally in the game and it should have meaning in the game", that is, it should be intrinsic.

Thus an educational game's engagement power would be spoiled if in this game students were asked to "step out of the game world" to do math learning (Van Eck, 2006)[31].

The majority of video games designed to provide mathematics learning fail educationally for one of two reasons: Either their designers know how to design and create video games but know little about mathematics education (in particular, how people learn mathematics) and in many cases don't seem to know what math really is, or they have a reasonable sense of mathematics and have some familiarity with the basic principles of mathematics education, but do not have sufficient experience in video game design[16]. Actually as Devlin points out, the majority of math education games seem to have been created by individuals who know just a little more than how to code, so those games fail both educationally and as games. Game designing is a highly demanding process where a team of experts from several different disciplines is required.

Most of math education video games, even until today, are focusing on basic skill but mathematical thinking is much more than mastery of basic skills. In Devlin's words: "math ed games are coming out like forced marriages of video games with traditional instruction of basic skills"[15].

Devlin advices that focusing on the improvement of basic math skill is not a good strategy, in fact he remarks that mathematics is a way of thinking about problems and issues in the world rather than a drill and practice process. Get the thinking right and the skills will come largely for free[15].

To confuse mathematical thinking with mastery of basic skills is akin to confusing architecture with bricklaying or playing a musical instrument with being able to play one musical scale[15]. Of course we need the basic skills but just as a mean to an end and not as an end in itself. These skills are much more easily acquired when encountered as part of mathematical thinking as one can learn the basic musical skills are acquired far more easily and effectively by trying to play tunes than by endlessly practicing the scales[15].

Challenges of Math EVG - Symbol Barrier

For many centuries, symbolic representation has been the most effective way to record mathematics and pass on mathematical knowledge to others.

According to Devlin maybe the most robust obstacle in the way of educational video games is the symbol barrier which emerges when somebody wants to do mathematics. In other words the problem is with the symbolic representation of mathematics. But in Devlin's word we are not so sure just how essential those symbols are? Before the invention of recording devices musical notation was the only way to store a music track yet music and musical notation are two different things. Just as music is created and enjoyed within the mind, so too is mathematics created and carried out in the mind[16].

Because video games are dynamic, interactive and controlled by the user yet designed by the developer, they are the perfect medium for representing everyday mathematics, allowing direct access to the mathematics (bypassing the symbols) in the same direct way that a piano provides direct access to the music[16].

There's a widespread belief that you first have to master the basic skills to progress in mathematics. That's total nonsense Devlin states. It's like saying you have to master musical notation and the performance of musical scales before you can start to try to play an instrument a surefire way to put someone off music if ever there was one[16].

1.7 Research Results, Virtues and Shortcomings of Educational Video-Games

1.7.1 Research Results

From 2000 to 2008 there was a period of vast acceptance of gaming technology in the research community[60]. It is incidental therefore that there are a lot of studies in the subject matter and a majority of them indicates positive effects from educational video games.

Bottino supports that there is a positive impact of video games to pupils logical and strategic reasoning skills[52] while Hui deduces that students applied some form of reasoning, deduction, pattern recognition while playing video games[13].

In the results of their study Kebritcki and Hirumi (2010), where they examined the effects of prior math knowledge, computer skills and knowledge of English on achievement and motivation, they found a significant improvement in the achievement of pupils who played computer games[**?**].

Yang and Chen (2010) determined that spatial skills were significantly improved after playing a math-logic puzzle computer game called Pentomino[61].

In Papastergiou's study [49], where she tests a game for Computer Science Teaching in High School, data analysis showed that the gaming approach was both more effective in promoting students' knowledge of computer memory concepts and more motivational than the non-gaming approach. Her results suggest that within high school CS, educational computer games can be exploited as an effective and motivational learning environment.

In Ke's study the participants who played video games did a lot less wild guess in certain games where learning content is situated within the gameplay (e.g. Ko's Journey see in Games Section) than in other games where learning content is not integral to the gameplay (e.g. DimensionM see in Games Section). It was also observed that participants tended to perform effortful game-based learning activities when they considered a

challenge as within their regime of competence (Gee 2003)[31].

Students who have followed geometry instruction with computer-augmented activities have benefited more in terms of knowledge of geometry concepts than students who have received more traditional geometry instruction (Funkhouser 2003)[48].

Pilli & Aksu illustrate in [48] in their literature review that there seems to be a correlation between Computer Assisted Instruction (CAI) and higher performance of students.

Their results showed that both the experimental group and the control group experienced improvement in mathematics achievement from the beginning of the intervention to its end. In addition it is indicated that students who were exposed to CAI with the video game they used (Frizbi Mathematics 4) significantly outperformed students who were exposed to Traditional Instruction on the mathematics achievement post-test in all the units (of the test)[48].

Squire who customized a commercial video game (Civilization III) for classroom application in his case study reveals that the game appeals particularly to the students for whom traditional education does not work. In his paper he outlines the benefits of and the obstacles to widespread game implementation[56].

—However bringing a commercial-quality educational game, like Civilization, into the classroom may create as many motivational problems as it solves. Roughly 25% of students in school complained that the game was too hard, complicated, uninteresting and they elected to withdraw from the gaming unit and participate in reading groups instead. Though research indicates that difficulty and complexity are part of what makes a game engaging[56]. The game actually forces you to learn about other civilizations in order to survive.

Offenholley capitalizes in her paper that Educational games have the potential to *i*) decrease anxiety, *ii*) increase motivation and the practice time of the students and also *iii*) deepen learning and understanding of mathematical principles [32].

As she quotes:

> Decreasing anxiety and negative messages about mathematics can result in increased student achievement, particularly for those who are susceptible to the negative stereotype that they are bad at math[32].

And one of the best ways to do that is to play games!

Demirbilek concludes that teaching mathematics using computer games is very important for consolidating abstract mathematical terms and removing or at least, in accordance with Offenholey[32], decreasing the anxiety of the students for math[37].

Costu et al in their case study revealed positive students attitudes towards educational video games in mathematics classes. As the state “many students in general don’t like mathematics and often perceive them as an unpleasant and hard-to-learn subject” but that was not the rule when the educational video game was implemented[54].

In Kebritchi’s literature review the findings of empirical studies revealed that educational video games: *i*) improved learners’ achievement in 9 out of 16 studies, *ii*) promoted learner’s motivation in 4 out of 16 studies and *iii*) made no difference in learners’ achievement or motivation in 5 out of 16 studies[43]. This literature review indicate that games were not always an effective learning tool at least not unless some conditions are applied.

Keibritchi in his study [43], whose purpose was to examine the effects of a series of modern mathematics computer games (DimensionM) on mathematics achievement and motivation of high school students, investigated the role of prior mathematics knowledge, computer skills and English language skills of the participants on their mathematics

achievement and motivation when they played the games. As he states the DimensionM games had a significant positive effect on students' mathematics achievement in the public high school setting. Students who played the mathematics computer games scored significantly higher on the district-wide math benchmark exam than students who did not play the games. It is notable that both control and treatment groups gained score from the pretest to post-test on the district benchmark exams after attending the school for 18 weeks. However, the treatment group who played the games, reported greater gain.

Ke's results indicated that students developed more positive attitudes toward math learning through a five-week gaming session in the math classroom, but there was no significant effect on students' cognitive test performance or meta-cognitive awareness development[31].

Another study states that games increase children's motivation and academic achievement within mathematics and science education in grades 3-8 (Klawe 1999)[7].

A study by (Rosas et al 2003) found that the use of games on portable devices led to improved motivation and learning outcomes compared to traditional teaching within primary school in mathematics and reading[7].

In their study Ayala et al apply this kinesthetic learning approach with the inclusion of mechanical and virtual devices in university level and their purpose was to demonstrate that this kind of learning offers a new experience in education, allowing better understanding of mathematical concepts, graphs and formulas and allowing students to take action in the learning process. As it is reported in [46] most of the students who participated gave positive feedbacks and where able to reproduce several graphs and patters using Kinect (A line of motion sensing input devices made by Microsoft for Xbox video-game consoles and Windows PCs[61])

Cankayas' results show that students who have positive attitudes towards mathematics course have also positive attitudes towards educational computer games. So it can be said that educational computer games can be used as a supportive tool to the other instructional methods[53].

Alzahrani's, who used Microsoft's Kodu game creator (see in Game Section), in his results indicates a positive correlation between educational video games and learning[6].

Additionally, tutoring in the form of game-based learning will lessen the possibility of an autocratic "top-down" learning approach from the tutor to the tutee, thus being more democratic and encouraging more self-disclosure of faulty or deficient thinking[31]. In his study Ke finds an improvement in students' state test performance after the game-based tutoring program[31].

Video games also help people to: improve their basic math abilities (Jones 2009); promote innovative mathematical thinking skills and is suggested to be an ideal medium to teach middle-school math as part of the teaching kit (Devlin 2011) as cited in [39] In his study Abdullah et al investigate the effectiveness of computer-based video games in facilitating children's learning of multiplication facts in mathematics.

Ruffin(2000) arrives at the conclusion that students' positive attitude towards Computer Assisted Instruction (thereafter CAI) plays a key role in the success of its implementation[48].

Why the research fails to decide whether VGs are Good or Bad

Methodological flaws in empirical studies are another factor that prevents us from drawing solid conclusions about the effects of instructional games on student learning. One frequent problem is lack of control groups in the studies and examining the effect of a

treatment without comparison to a control group is problematic as Kebritchi et al quote from Mitchell&Savill-Smith (2004) and Vogel et al (2006).

Virtues of Video Games in Education

Video Games have a plethora of good features which can boost education to the new era that Devlin so strongly suggests.

Games that encompass educational objectives are believed to hold potential to render learning academic subjects more learner-centered, easier, more enjoyable more interesting, and thus, more effective (Prensky 2001).

I give some of the reasons for which games are an effective and powerful tool in the arsenal of education below:

- Direct feedback on the player's actions

  As Bottino cites, other from providing a right/wrong assessment, this feedback is contextualized can support the pupils in error comprehension which can learn from their failures of their actions(Werts, Caldwell & Wolery 2003)[52, 7]

- backtracking

  As it is defined in [52] i.e. the possibility to retrace one's steps and reflect on them

- graduation in the level of difficulty

  The teacher or even the student are able to configure the level of difficulty

- Specific tips or hints

  At the users request in order not to be stuck in the same place for a long period of time and get frustrated

- Recognition of patterns

  Which is quintessential and bound with human nature and also

- reduce the fear of failure

  Failure is an essential part of the learning process and educational video games can be a powerful and motivating digital environment for learning where players can interact and explore each subject without the fear of failure[20]

- Self-Assessment

  Video-games allow opportunities for self-assessment through the mechanisms of scoring and reaching different levels(Oblinger 2004)[7]

- they support active, experiential (learning by doing), problem-based learning (Oblinger 2004; Garris, Ahlers & Driskell 2002)[7, 31]

- invoke intense engagement in learners (Malone 1981; Rieber 1996)[31]

- foster collaboration among learners (Kaptelin & Cole 2002)[31]

- create personal motivation and satisfaction[43]

- accommodate multiple learning styles and skills[43]

This is where video games provide a huge advantage particularly for students who have grown up in today's instant-feedback, multi-tasking era of computers, social networking, instant messaging and sophisticated, high quality video game technologies[15].

Shortcomings of Educational Video Games

Along the virtues of Educational video-games there are some problems, drawbacks and critics against their massive implementation in education

Provenzo, the most outspoken and often-quoted of the video game critics, raises four main concerns with video games as quoted in [57]. Video games:

1. can lead to violent, aggressive behavior,
2. employ destructive gender stereotyping,
3. promote unhealthy "rugged individualist" attitudes, and
4. stifle creative play

Thusfar, video game research has found no relationship between video game usage and social maladjustment[57].

Kapper quotes in her thesis Rice's(2007) argumentation that video games are "mindless forms of activity and do not hold an affinity to strong instructional content" and also associates them with violence.[60] In addition Rice identifies several barrier that can add to this negative perception: specifically he cites *i*) game graphic quality, *ii*) lack of classroom time for game play, *iii*) inadequate representations of learning objectives when deploying video games as a teaching mechanism [60].

Research on the impact of video games on aggression and violent behavior has consisted primarily of two types of studies: (a) experimental designs where players' amounts of aggression are measured before and after playing violent games versus non-violent games, and (b) correlational studies that look for patterns of behavior in frequent video game players. The majority of these studies took place in the early 1990s, which means that video game research is outdated as it is approximately two generations behind home console developments. Regardless, research until now has been inconclusive[57].

Entering a virtual world is as old as storytelling, and has been a continued tradition through printed literature, television, film, and now interactive digital media[57]. Taken in this historical context, critics' concern with video games seems awfully familiar; critics were concerned that sound and color would ruin films[57]. It is the nature of things that change is fought until it has established its ruling.

In addition playing games does not appeal to every student. Students may be distracted by game-playing, and thus, not achieving the learning goals (Miller, Lehman & Koedinger 1999). Further, students may fail to extract intended knowledge from a complicated gaming environment (Squire, 2003)[31]

One frequently raised issue is the lack of empirically tested educational video games with strong theoretical background. In addition many games fail to integrate educational aims with the core game features Young et al 2012. Most of the educational video games in the market are still simple drill and practice games which aim for calculation fluency[15].

As Gunter, Kenny and Vick warn in [47], "We are witnessing a mad rush to pour educational content into games in an ad hoc manner in hopes that players/learners are motivated simply because the content is housed inside a game".

"We should not generalize from research on the effectiveness of one game in one learning area for one group of learner to all games in all learning areas for all learners"[47].

Necessity of Educational Video Games

If you ask teachers of mathematics you'll definitely hear them complain about their students, that they come in late, they leave early, do not do their homework and text message each other while in class. It is important to surpass the usual cranky complaints of the teachers concerning the new generation and listen to the problems underlying all these complaints: the need for better student engagement, motivation and attitude[32]. Young students have an uncanny aptitude for mathematical thinking in this gamified environment as Elliot states[23].

2

The Number Navigation Video Game

The Number Navigation Game (hereafter, NNG or NN) was created by a team of researchers led by Professor Erno Lehtinen at the University of Turku, Finland. It is a video game aiming to promote arithmetic problem solving in Elementary School students(age 10-13) by trying to improve, their flexibility with and adaptivity to different settings of calculations. Another viewpoint, having seen and played the game in this research, is that it fosters strategic and reasoning abilities in pupils by engaging them with mental calculations.

For the description of the game i have mainly been based on the unpublished article of Lehtinen et al [19].

2.1 Educational goal of the NN game: The development of mental calculation ability

Mental calculation is a process which comprises arithmetical calculations using only the human brain, with no help from calculators, computers, or pen and paper. In today modern age of technology mental calculations is a slowly perishing skill like navigation which has been substituted by GPS technology.

I will argue that mental calculations are an essential skill, even in the era of pocket calculators, and must be implemented massively. Thompson sums up in [29] to give four reasons for teaching mental calculations:

1. Most calculations in adult life are done mentally
2. Mental work develops insight into the number system (commonly refered to as "number sense") Number sense is our ability to judge and compare sizes of collections without counting[15]
3. Mental work develops problem-solving skills
4. Mental work promotes success in later written calculations

In other words those mental calculations are honing our brains.

But is it possible to implement this skill in our education and if so how can we achieve this result?

Threlfall gives four attributes that in his view assist the development of flexible mental calculation:

1. Good knowledge of number facts (fitting to the age)
2. Clear understandings of what can be done legitimately with numbers e.g. when the order can be changed and when it cannot, how numbers can be split and dealt with as parts, reverse operations, the behavior of zero and so on
3. Well developed skills (fitting to the age) such as counting skills and automated mental calculations
4. Positive attitudes, such as the confidence to "give it a try" and not being put off by immediate lack of success

Threlfall suggests that strategic methods are those that come about when numbers are treated in a holistic way, as quantities rather than digits. For example 7+8 is 15 because 7+3 is 10 and 8 is 5 more. In another example the adding of one number to another first by adding the tens and then the ones separately is more suited to 55+24 than to 33+29 whereas rounding a number before adding, and then compensating, is more suited to 33+29 than to 55+24. As he states a child who makes "good choices" of this kind is expected to be more effective in calculating.

Threlfall reports in his article four number partitioning strategies for addition in a list as they are quoted in the British qualification and curriculum authority in their issue in 1999[51].

- **"Using multiples of 10 and 100"** by partitioning one or both numbers into tens and ones, e.g. 23+45=40+5+20+3 or 55+37=55+30+7=85+7
- **"Bridging through multiples of 10"**, by partitioning one of the numbers to provide the difference between the other one and the higher multiple of ten, e.g. 57+14=57+3+11 or 57+13+1
- **"Compensating"**, by rounding one number up to a multiple of 10, adding that to the other number, then subtracting the amount used to round up, e.g.38+69=38+70-1
- **"Using near doubles"**, e.g.38+35 is double 35+3

For multiplication and division Threlfall suggests the strategies listed UK government's National Numeracy Strategy issue from 1999[51]:

- Using related facts and doubling or halving
- Using factors
- Using closely related facts already known **
- Partitioning and using the distributive law
- Using the relationship between multiplication and division
- Using known number facts and place value **

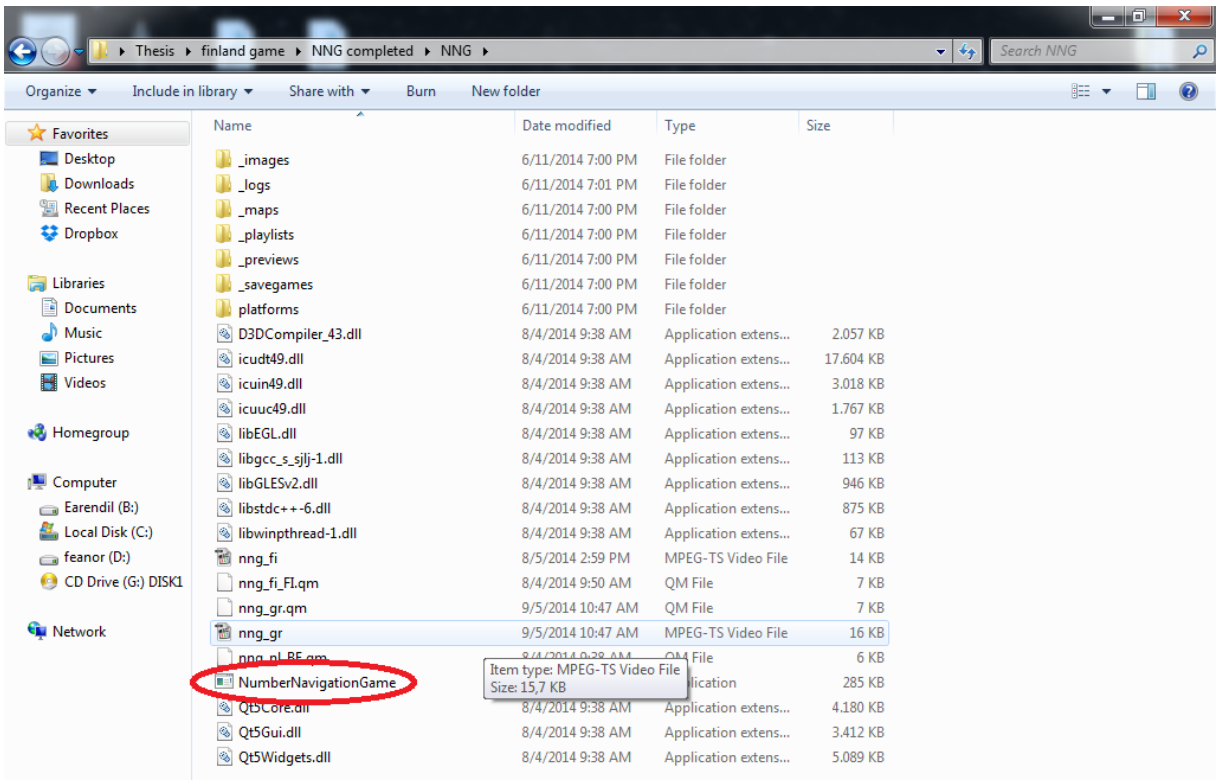


Figure 2.1: Screenshot of the Directory File of NNG, the red-circled file is the executable file of NNG

The concept of flexibility in mental calculations as Threlfall grasps it in his article refers to the choices that one can make in calculating a mathematical operation e.g. 27+58, 12*6 etc. In other words the more choices the student will have the merrier it will be for him in achieving his goal i.e. the mental calculation of a mathematical operation.

2.2 Interface

The game is designed for Windows OS and runs through an executable file (.exe), it does not require any installation and thus can run through any portable device as long as you have the directory file (see figure 2.1).

The requirements of the game are minimal (i.e. no advance graphics), it is almost equivalent with a flash game in your Internet browser. In addition there is no music in the game so sequentially no need for speakers and also no need for Internet connection.

Opening the game from the executable file the player sees the main screen of the game (see figure 2.2) where he can discern an $8x8$ grid of squares. Each square represents a unique stage of the game. Starting the game the player can see only 4 squares (the central ones) the rest of the squares are inaccessible to the player and covered by "fog of war" using the video game jargon [61]. Those 4 central stages constitute what we will call initial level or level zero. After the player completes the initial level's stages, he gains access to first level's stages where he has to face stages of greater difficulty and so on and so forth until the third level which is the last one. The first level consists of 12 stages and optically it circumscribes the central square consisting of the 4 initial stages. Accordingly the second level consists of 20 stages and circumscribes the first level stages and lastly the third level consists of 24 stages and circumscribes the second level stages. Within a

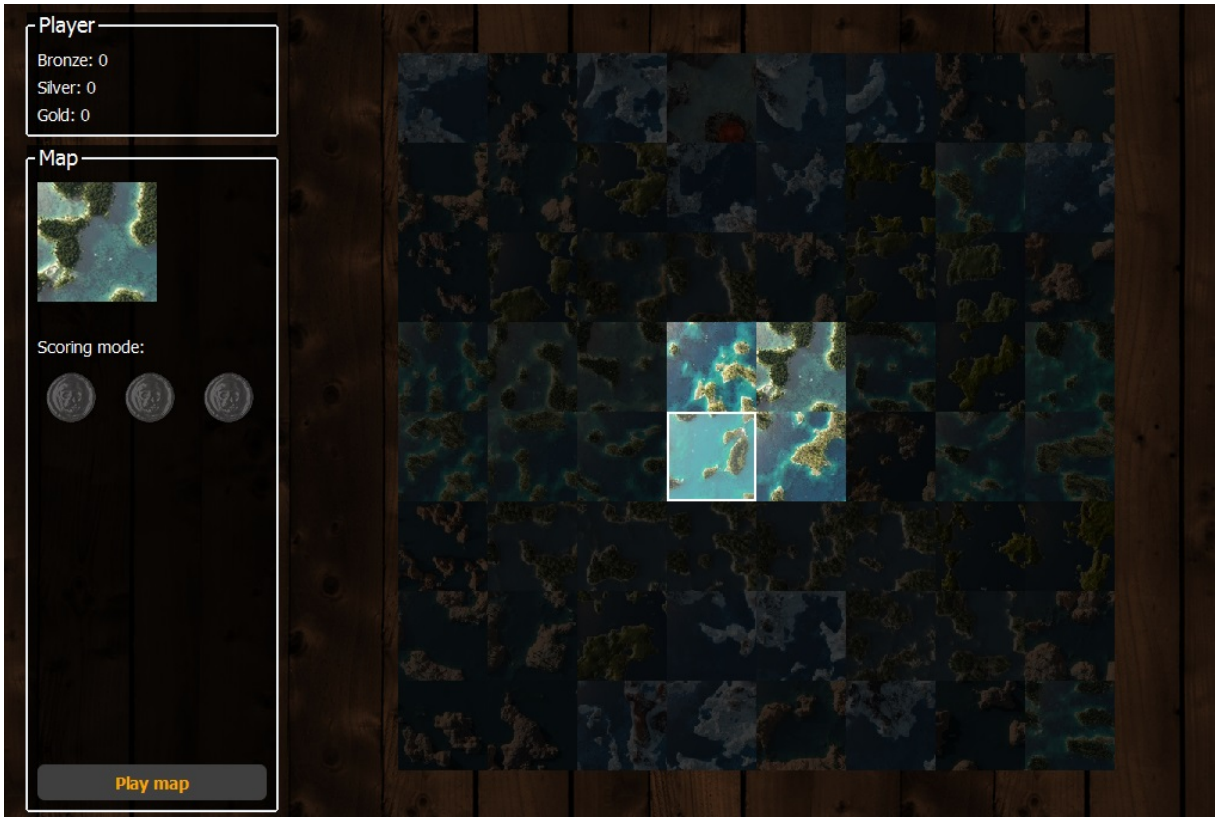


Figure 2.2: Screenshot of the Main Screen of NNG

level the player is free to choose the order that he wants to play the stages, in other words every level consists of a "sandbox" world if you will. You can see the levels in figure 2.3.

On the left side of the main screen there is a sidebar where the player can keep track of each stage's statistics and also see the scoring mode (energy or moves) of the particular stage. The player's achievement on each stage is represented by the medals that he earns. There are three possible medals Gold, Silver and Bronze with gold being the best and bronze the worst. If the stage has been completed, you can see in the sidebar the medal that you have received. To get access to each stage the player have to push the play map yellowish button on the down left corner of the screen.

When the player pushes the play map button he is taken to each stage's screen. The basic rubric for the stages here is a terrain map picture which comprises of a variety of little and bigger islands scattered across the sea over which we see a superimposed one hundred square grid. In each stage some of the numbers are inaccessible due to the map terrain e.g. there is an island that blocks you from going to the numbers 21 and 31 in figure 2.4. You can see a typical stage screen in figure 2.4.

The players task is to control a ship which collects the materials with which he will build his City taking under consideration each stages scoring mode. There is a fixed starting point on each i.e. the harbor which for example in figure's 2.4 is located at number 4 and is signaled by the anchor image on the map. In every stage there are 4 specific materials that the player must gather and are always given at the same order: *i*) wood,*ii*) brick,*iii*) stone,*iv*) iron. The player has retrieve one building material in order for the next one to appear. In figure 2.4 the first material, i.e. wood in the specific example can be seen at number 11.

The scoring mode can be seen in the left sidebar under the numpad, in figure 2.4 we

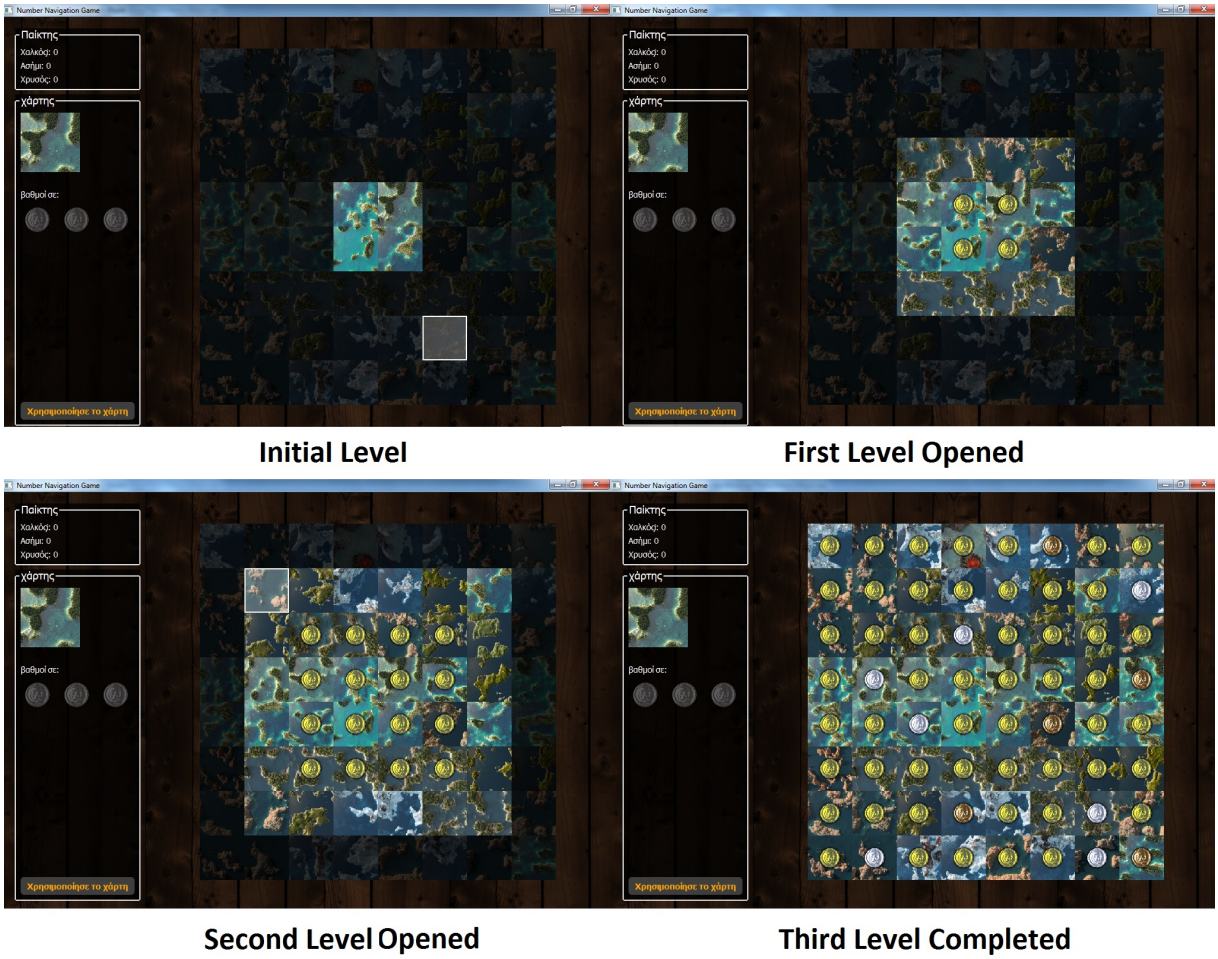


Figure 2.3: Initial Level, First Level, Second Level and Third Level

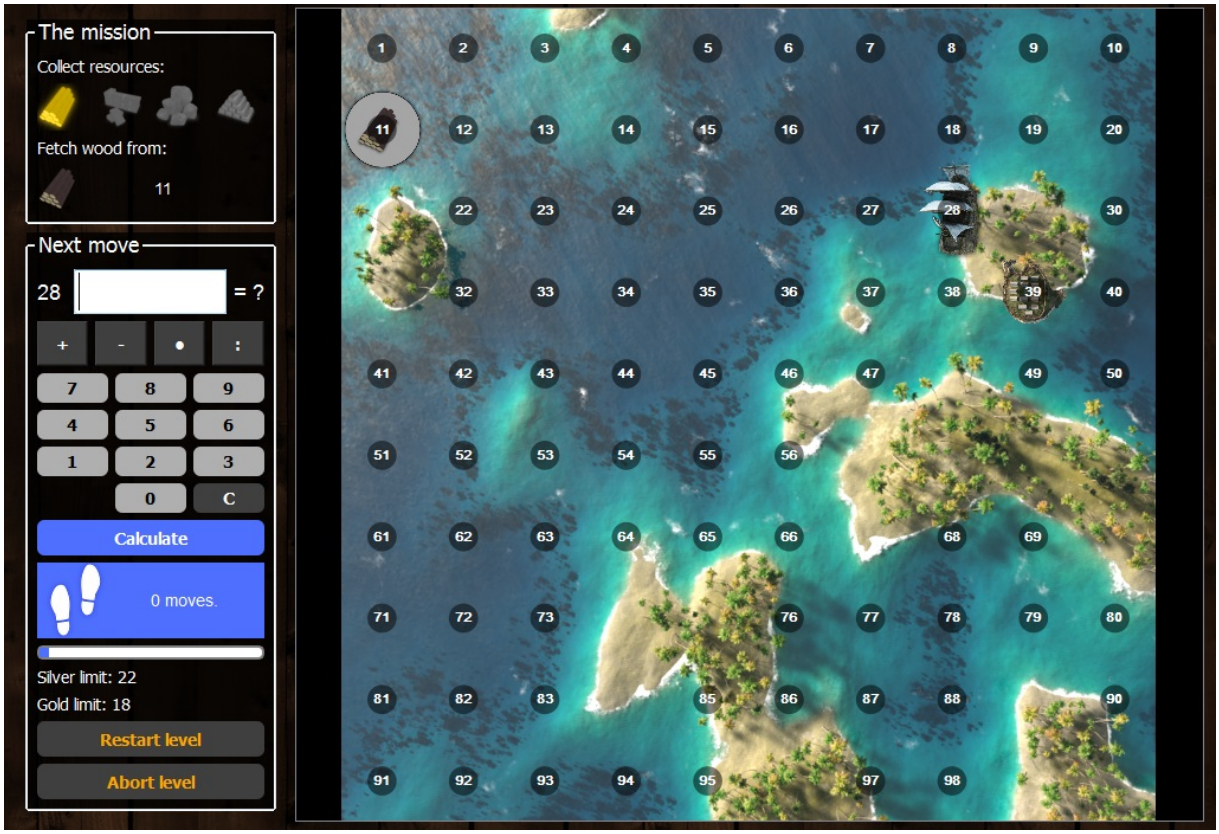


Figure 2.4: Sample Stage Picture in Moves Mode

can see in the blue color frame a footprint icon which designates that this map's scoring mode is moves. Each game mode will be described in detail further on. Below scoring mode frame there is a bar which depicts the moves that you have made in moves mode and the energy that you have spend in energy mode (see figure 2.5 for energy mode). In each figure 2.4 and figure 2.5 we have made so far 0 moves and spend 0 energy. Below this bar there is a text indicates the score limits for the particular level. In figure 2.4 we can see that in order to get a gold medal we have to make 18 moves or less, if we make a number of moves from 19 to 22 we get a silver medal and everything from 23 and above gives us a bronze medal. In order to proceed to a next level e.g. to go from initial level to first level the player has to complete 75% of the stages with silver or gold medal. The player also has the ability to restart a stage if he has made some mistake or just wanna improve his score and also the ability to quit button if the get bored or want to play another stage.

2.3 Game Mechanics

The goal of the game is to navigate across the seas, collecting the building materials in order to construct your city. The player can move the ship by inputing operations and numbers in order to get from one number (i.e. game location) to another. This gets done through the in-game designed numbpad, for example let us say that the player wants to move from number 28 to number 11 where the wood lies in figure 2.4. The optimal solution in moves mode is to do this by subtracting 17 from 28 and thus getting to the building material in one move (see figure 2.6). So the player has to input the right

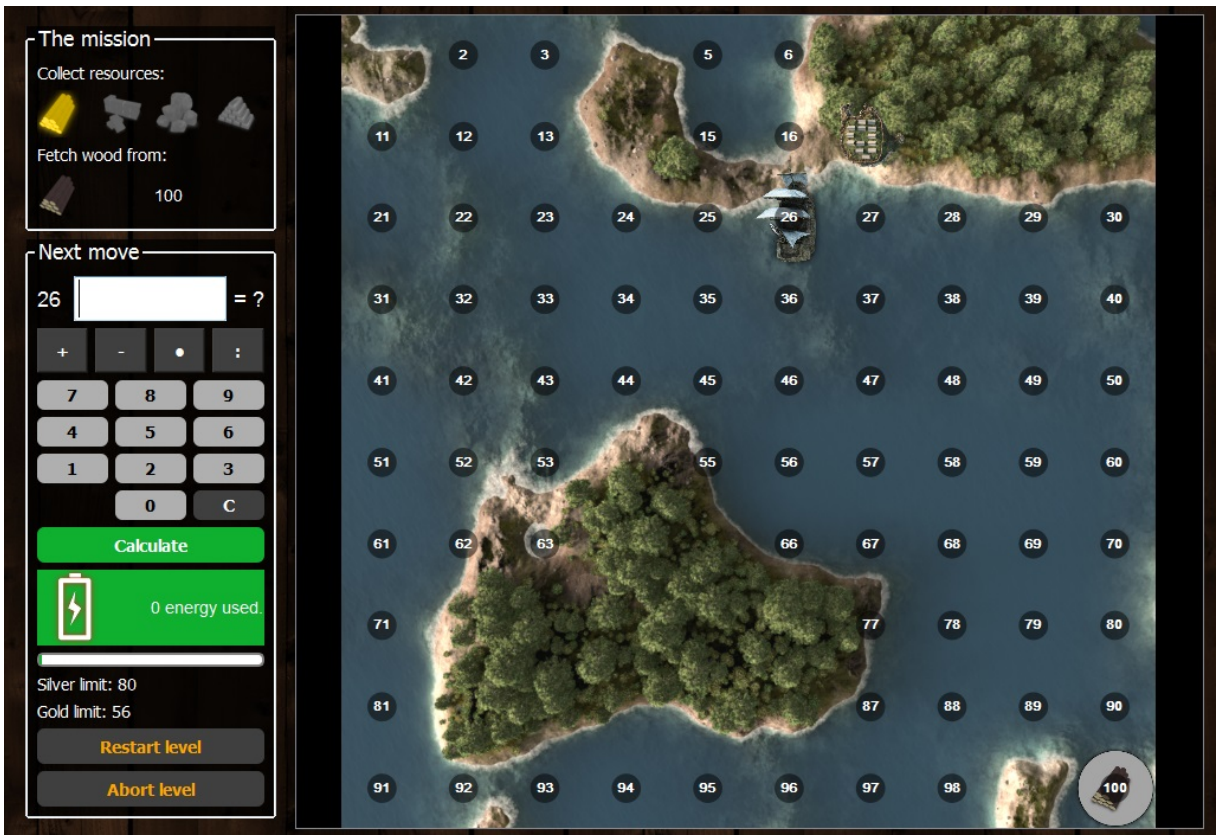


Figure 2.5: Sample Stage Picture in Energy Mode

mathematical operation, in this case subtraction represented by -, and the number that will define what will be subtracted from the initial number. The mathematical operations that the player can write in the command box are the 4 usual operations i.e. addition, subtraction, multiplication, division.

If the player wanted to go to 21, she/he would observe that the number would be blocked by the terrain, then he/she would just have to subtract 7 from 28. The player would then observe the hitting in the island animation which is designated by a red intermittent line and a red X on the point that the boat would hit the land (see figure 2.6). This is only logical because ships can't, at least not in general, sail over land. Having done this "mistake" and here i use quotation marks intentionally in the word mistake, the player does not get penalized. There is no way to die or get punished in NNG. The same thing will happen if the player gives an input that would exceed the dimensions of the map and would get him outside of the 100-grid e.g. $28 - 30 = -1$.

There are two scoring modes in the NNG that designate the two different ways of evaluating the player's input.

2.3.1 Moves Scoring Mode

The **moves mode** where the player has to make as little moves as she/he possible can in order to get all 4 building materials. A move is designated by an operation. The move limits are designated by the text below the mode frame as it was mentioned above. The moves mode is signaled by the footprints icon in the blue frame. The aim of the moves scoring mode is for the players to understand that the optimal route is always the direct route of course taking into account the harbor, the position of the material and the map's

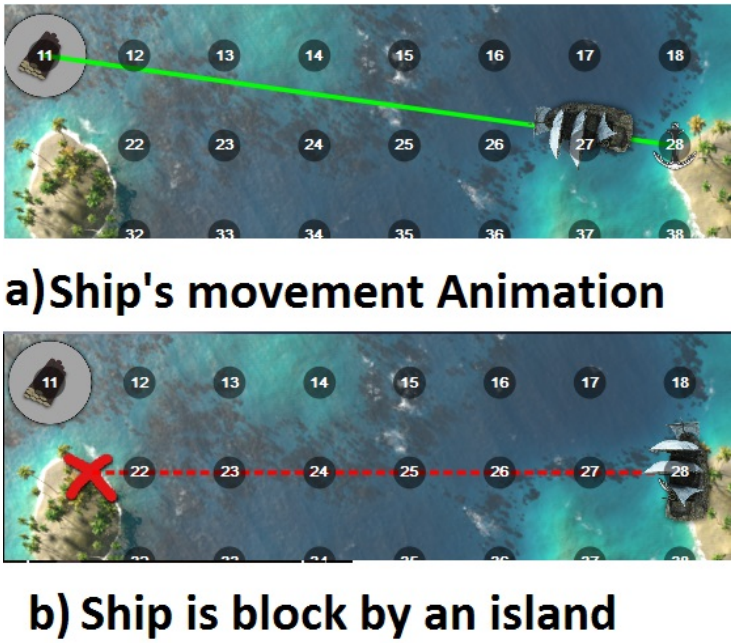


Figure 2.6: (a) Ship's movement animation (b) Ship is blocked by an island

geographical layout.

An example would set things straight. Let's say that the player wants to get from 28 to 11, he/she can choose a vast variety of combination one of the could be subtracting 17 from 28 and thus gets to the material in one move (this operation is considered a move), another possible way is to go from 28 to 18 by subtracting 10 and the from 18 to 11 by subtracting 7 thus making two moves. The player should also keep in mind that he has to return to the harbor so whatever number of moves she/he makes to get to the material has to be doubled.

2.3.2 Energy Scoring Mode

The **energy mode** where the player has to consume the lowest energy that he/she can in order to get all four building materials. The energy is the input numbers that the player writes in the command box . The energy limits are designated by the text below the mode frame. The energy mode is signaled by the battery icon in the green frame. The aim of energy mode is to encourage the use of all four arithmetic operations as well as the use of a vast number of combinations.

Let us also clarify this with an example. In energy mode if a player wants to move from 26 to 100 (see figure 2.5) and chooses to do this in one move he will write in the command box 26+74=100 and will get to the material. With this act she/he will have consumed 74 energy, so bearing in mind the energy limits of this stage which are 56 for gold medal and 80 for silver, he/she would have lost the gold medal and would not had great chances in taking the silver either. So in energy mode the player has to find an energy efficient route, meaning by this that he/she must input small numbers in the command box. The optimal way to get to 100 from 26, in means of energy, is to subtract 1 thus go to 25 and multiply by 4 getting to 100 having spend only 5 energy to pickup the material. The student-player though is not obliged to find the optimal route, only a solution that will make him get the material without spending too much energy. In

Figure 2.7: Pirate and Hitting Upon the Pirate

addition as in moves mode the player must always remember that whatever amount of energy he/she will consume to get to the material has to be doubled because she/he has to return the materials to the harbor and get his new mission.

Upon reaching the material, a pop up window will appear informing the player that he/she needs to return it to the harbor. In this pop up window the player can see his city creating from scratch with a specific sequence of photos, same for every stage. How the player go back is entirely in his judgment. He can do this by reversing his/her initial operations or by trying a different route.

2.3.3 Game Features

Apart from the minimum moves and energy efficiency rules the game has two additional features: the pirates and the hidden operations. After picking up a building material in some levels the pirate appear right in the last location that you where before going to the material. The aim of this feature is to prevent the player from going back to the harbor the same reverse way that he/she got to the material. The pirate is designated by a human skull in a black font icon. The player cannot stop at the pirate's location (the exact number of the pirate icon) but he/she can pass him/her over. See figure 2.7.

The hidden operations feature appears only in the third level of stages where the difficulty of the game is the highest. In the stages which incorporate this feature some of the operations are inaccessible to the players. That reduces the vast variety of different combinations that a player can make thus adding to the complexity of the game. An example of such a stage can be shown in figure 2.8.

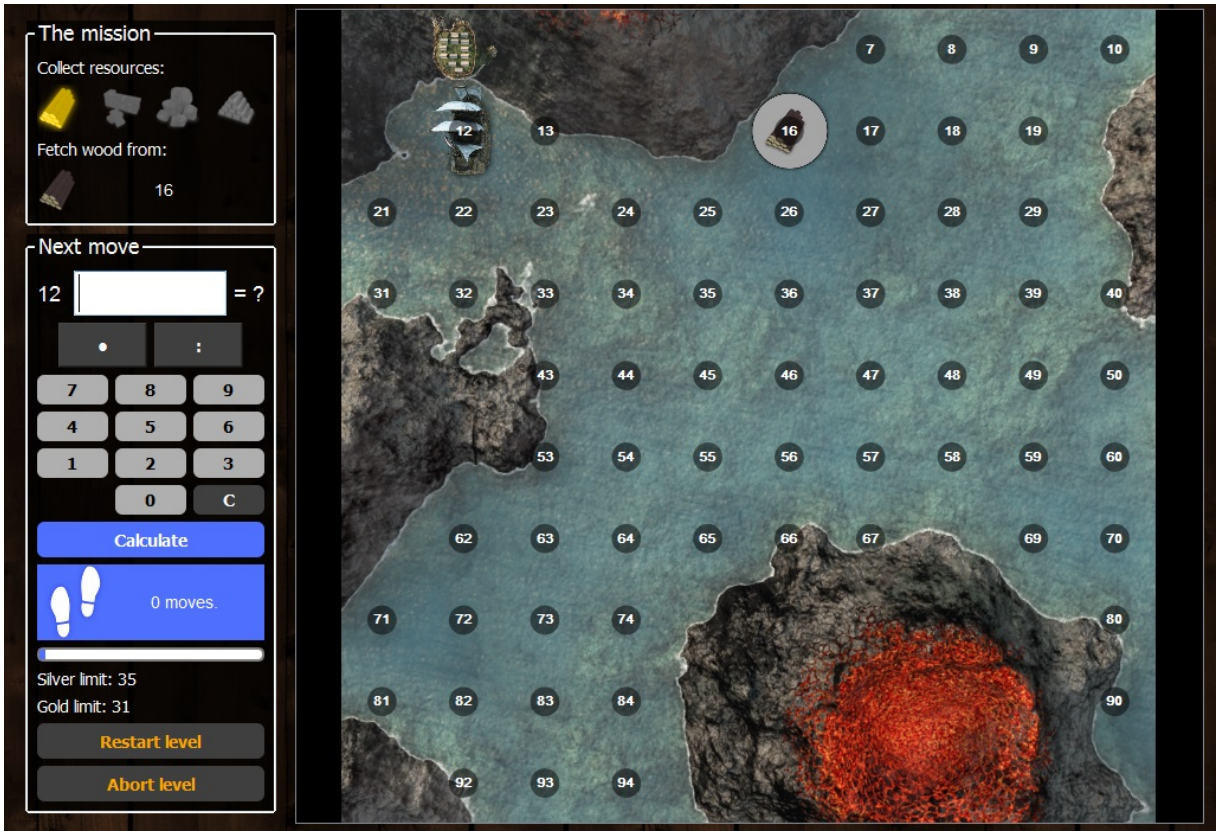


Figure 2.8: Arithmetic Operations of Addition and Subtraction Are Hidden

2.3.4 Customization

The game is targeted to elementary school students of ages 10-13, as it has been said above, but it is customizable and can also be used either for younger children using the only the moves mode stages or, and this is the case of this research, even adults using mostly maps with energy mode and hidden operations.

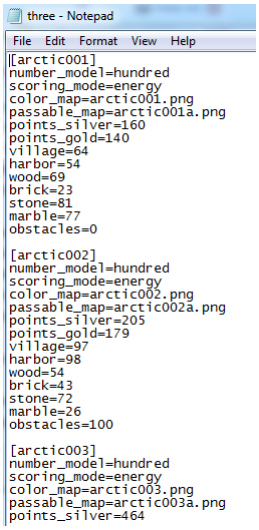
Another customizable feature of the game is the recalibration of the limits for gold, silver and bronze medals in order to make stages more challenging or easier to be dealt with. This process has to be done for each stage separately.

There is a text file in the directory of the game which in which you can make any change you want in a specific stage. As you can see in figure 2.9 you can customize any feature of any stage from the mode of the game to the position of the materials, the map images etc.

Translation of the Game

The game was originally created from the Finnish Team thus the game's language was Finnish. The translation of the game was carried away firstly from the Finnish Team from Finnish to English and then from Constantinos Christou from English to Greek. The translation of the game is procedure that can get easily done if you know the language of the written file. To change the language of the game you just need to translate the dictionary files in the wanted language. For example for the Greek translation K.Christou translated the dictionary file in the directory i.e. *nng_gr.qm* from English to Greek.

Is there such a mode built in the game? If not, then it is not necessary to have this



```
three - Notepad
File  Edit  Format  View  Help
[arctic001]
number_model=hundred
scoring_mode=energy
color_map=arctic001.png
passable_map=arctic001a.png
points_silver=160
points_gold=140
village=64
harbor=54
wood=69
brick=23
stone=81
marble=77
obstacles=0

[arctic002]
number_model=hundred
scoring_mode=energy
color_map=arctic002.png
passable_map=arctic002a.png
points_silver=205
points_gold=179
village=97
harbor=98
wood=54
brick=43
stone=72
marble=26
obstacles=100

[arctic003]
number_model=hundred
scoring_mode=energy
color_map=arctic003.png
passable_map=arctic003a.png
points_silver=464
```

Figure 2.9: Txt File For Stage Modification

paragraph here. In general, I don't see why you need to explain this. The argumentation is not very sound, either (I would argue that competition is very much a feature of many games.

2.4 Classification of NNG

From the viewpoint of motivation it could be argued that the player's goal is to build a city, or even the smaller tasks that it consists of (e.g. bring wood) and if the player does it for the fun of it (or for any other need that he has to satisfy according to the definition of intrinsic goals that has been given in Preface) then this goal could be an intrinsically motivating one. This could hold to be true, at least for the most engaged players. Concerning the medal acquisition goal of NN now, the player gets rewarded with a virtual badge according to his in-game performance which consists an extrinsically motivating goal (according to the definition of extrinsic goals that has been given in Preface).

Concerning the integration of the mathematical context in the game it would suffice to say that any math that arises in the gaming environment should be a means to an end and not the end in itself. In NN if we exclude the symbol barrier the math arise naturally and do not present a major hurdle that causes the player to give up. It seem perfectly natural to the player that he or she has to perform a certain calculation in order to complete the task at hand. Moving the ship through adding, subtracting, multiplying and dividing is an innate feature of the game. Hence NN is an integrated game because the math content of the game cannot be swapped without changing the innate structure of the game i.e. you can't play the game without doing math (e.g. calculations).

Last but not least an extensive list of the game features which are included in NN, following Malone's norms, is: *i*) virtual assets, *ii*) feedback, *iii*) ranks and levels, *iv*) a set of rules and *v*) specific tasks (i.e. get the X material which lies on the Y square of the 100-grid) .

3

Methodology

3.1 Aims of the Study

The aim of this empirical study is *a*) to evaluate the Number Navigation Game in terms of its potential to promote mental calculation skills in otherwise mathematically-versed individuals, and *b*) to examine the beliefs towards VGs in education of and the game's appeal to, those highly trained mathematics educators.

The study was a quasi-experimental intervention, with an one group (of 16 participants) pre/post test design. As may be evident, the NN game was tested with educated adults who were highly trained in mathematics and had considerable teaching experience, in a single 2h gaming session. Thus, several adaptations had to be made to the game, as well as to the tasks of the pre/post test, compared to the tasks in the studies of the Finnish Team. The customization followed after a pilot study, and is presented briefly below.

3.2 Pilot study and "Customization"

The pilot study was conducted with one participant of the intended population and guided the researcher to make many changes in the initial research design.

Epigrammatically, in the original version of the pre/post tests, there were several items of the same type, but of gradually increasing difficulty. However, the easier items proved to be too easy for this participant and were consequently dropped. This resulted in a shorter test, consisting of the most challenging tasks, appropriate for the level of expertise of the participants. Moreover, the new tests were less demanding in terms of time consider that initially the pre/post test time was approximately 30-40 minutes which was not manageable in this research's framework.

Concerning the gaming session the goal that was set for the participant was to play for as much as he could in order to complete as many levels as he could with the maximum being the completion of the third level of the game (an unrealistic goal). This goal proved to be excessive, unnecessary and far-fetched and also created stress to the participant. It took him almost three hours to complete the second stage, excluding the recess time, and he was exhausted, stressed and fed up in the end ((in the participants words, Why make an intervention with an awfully boring game just teach the conventional way).

Further more, after interviewing him it was obvious that starting from the first levels of the game (i.e. zero level) would be an unwise choice. Indeed, most of the early levels of the game are in the Moves mode that would be trivial for the specific population; moreover,

the early levels were easy also in terms of calculations and challenges posed (e.g. pirate appearances, terrain difficulties). Thus, including the early levels in the gaming sessions wouldn't pose the right challenge for the particular population and it would just cause discomfort to the participants without a forthcoming gain. Therefore, it was decided not to include the early levels in the present study.

After extensive discussion with the Advisor of this thesis and Erno Lehtinen of the Finnish team, it was decided not to modify the gold and silver medal limits of level's 2 stages.

3.3 Participants and Demographics of the Sample

This study's sample is comprising of 17 Greek speaking, post-graduate students from the post-graduate program in Mathematics Education of the Mathematics Department, National Kapodistrian University of Athens. Eleven of the participants were female.

One of the participants holds a bachelor in Education and Pedagogy from the University of Thessaly (4 years); three hold a bachelor in Applied Mathematics and Physics Department from the National Technical University of Athens (5 years); and thirteen hold bachelor degrees in Mathematics from various Greek Universities (4 years). Due to research ethics, the names of participants are not revealed.

According to Prenskian taxonomy [45], 12 of the participants were Digital Natives (born from 1980 onwards); and 4 of them were Digital Immigrants (born before 1980).

All participants had teaching experience either as school teachers (3 of the participants) or as mathematics tutors (14 of the participants). Their teaching experience varied from at least two years (seven participants); at least six years (seven participants); at least six years (seven participants); and at least ten years (three participants).

Regarding computer use experience, four participants reported that they were light to frequent users of computer technology, and 13 stated that they were proficient / regular users of computers.

As for video game playing, eight of the participants stated that they never play video games; five reported playing video games 1-3 times/week; and four reported playing video games 3+ times/week.

Finally, the participants were asked to grade their teaching practice on a 1-5 Likert scale item where 1 represented Directed (teacher-centered) instruction and 5 represented Inquiry/Investigative (student-centered) instruction. One of the participants responded with 2; twelve with 3; and three with 4.

The demographics of the study have been filled by the participants in a questionnaire form that was provided to them and cross-checked for their validity by the researcher. Detailed information regarding the demographics questionnaire items are presented in the Demographics Questionnaire section below.

3.4 Design & Procedure

A summary of the study can be seen in figure 3.1.

First, the participants filled up a demographics questionnaire (see the specific section below), a procedure that took approximately 1-2 minutes.

Then each participant individually answered a pre-test targeted on their mental calculation ability before the gaming session intervention. There was a time limit for this

Figure 3.1: Summary of the Study Image

Duration	2 minutes	14 minutes	2 hours	14 minutes	20-30 minutes
Procedure	Demographics Questionnaire	Pre-Test	Gaming Session	Post-Test	Open-Ended Questionnaire

session which set to be 14 minutes.

A brief introduction to the game environment, the game rules and it's mechanics followed where the researcher explained carefully the concepts of the game and tried to clear the vague and fuzzy spots.

The gaming session lasted two hours. The participants were offered 10-15 minute breaks after completing one hour of playing the NN game, in order to keep them refreshed and as comfortable as possible. Each participants gaming time was measured rigorously in order to not exceed the time limit.

Following the gaming session, each participant answered a post-test, similar in every aspect (structure, difficulty and duration) to the pre-test.

Finally, each participant filled in an open-ended questionnaire concerning various aspects of their experience with the NN game and their stances towards mental calculations and video game implementation in education. No time limit was imposed on this session. The duration was approximately 20-30 minutes.

The whole process was calculated to be around 4h (5h considering the recess time) and it got done in a single session, with the exception of the open-ended questionnaire part for some of the participants, who asked for a different session due to work or family obligations. Of course the researcher complied with this request to help them and ease any inconvenience that would arise to their daily program.

It should be noted that the participants were requested to bring their own laptop in order to play the game there, but also to complete the digital open-ended questionnaire. In some cases were a specific participant hadn't had a laptop of his own the researcher provided one. The game and a copy of the digital open-ended questionnaire were given in a single directory folder to the participants with a USB stick.

Furthermore let me emphasize that the participation to this research was fully voluntary. The importance of participation was emphasized and also the participants were personally thanked for contributing towards the creation of the present study.

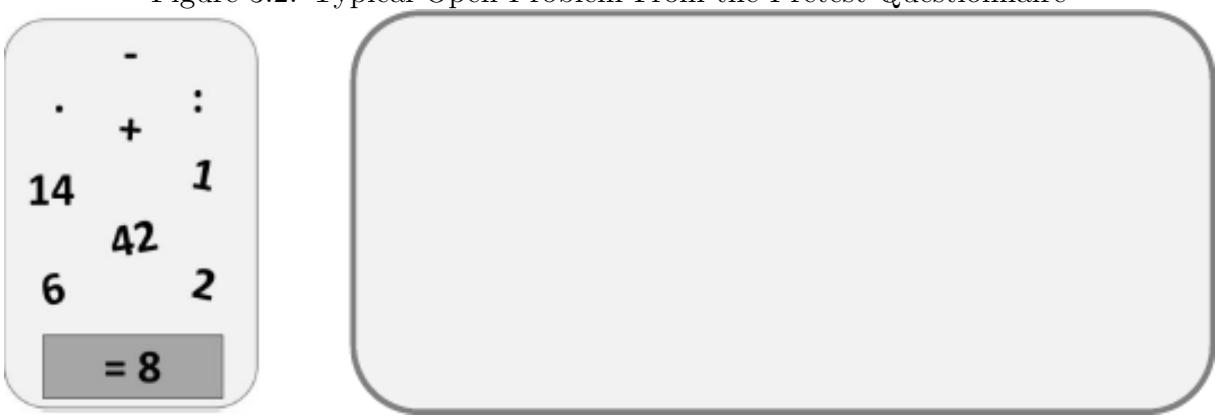
3.4.1 Data collection

In this study the main research tools were in-field observation, questionnaire analysis (pre/post tests, demographics, open-ended questionnaire), a think-aloud verbal protocol while playing the game and while filling in the open-ended questionnaire. This multiplicity of tools was used attempting to achieve data triangulation (utilize multiple forms of data sources).

Think-aloud protocol was applied according to Ke [31] and based on Ericsson and Simons (1993) talk-aloud method. These researchers developed an open-ended protocol to facilitate participant thinking but not to influence what they said. Participants were prompted to report whatever goes through their mind, such as what they were looking at, thinking, doing, and feeling, as they went about their task. The following instruction was given: As you play the video game, please speak out aloud everything that you want

to remark. Try to say everything that goes through your mind, such as your thoughts, feelings, and choices about what you are doing and reading on screen. If the participants did not think-aloud, the researcher gave prompts like: What are you doing now? Why did you do that? What made you arrive at this decision? How are you feeling? or So now you are... The most important, in the view of the researcher, participants verbal protocols were recorded and were kept in mind during the analysis of the open-ended questionnaire.

Figure 3.2: Typical Open Problem From the Pretest Questionnaire



3.5 Research Design

3.5.1 Pre/Post Tests

The pre/post tests, presented in full in Appendix B3, were designed with a view to be equivalent in terms of number and type of items as well as of difficulty.

The tests were divided into three parts, each consisting of a specific type of items, namely Open Problems, Constrained Problems, and Multiple & Fill-in Problems.

The time duration of the test was set to 14 minutes, 3 minutes for the Open Problems, 5 minutes for the Constrained Problems and 6 minutes for the Multiple & Fill-in Problems. The decision to set the time limit to 14 minutes stems from the pilot study's results. The time measurement was conducted rigorously by the researcher following a standardized procedure.

Open Problems

The first part is the open problems consisting of 4 items and originates from the work of Lehtinen's team. Specifically this Operation Production Fluency Task aims to measure students' ability to recognize and use different numerical characteristics and relations in arithmetic problem solving. The test was developed based on the results of pilot studies conducted by McMullen et al[10]. A sample open problem item can be seen in figure 3.2.

This part consisted of 4 items and originates from the work of McMullen et al. as it is described in [10]. This Operation Production Fluency Task, as it is called in [10], aims at measuring the individual's ability to recognize and use different numerical characteristics and relations in arithmetic problem solving. A sample open problem item can be seen in Figure 3.2.

The main idea of the open problems is that the participant is given 5 number and the 4 operations and has to make as many combinations as he/she can possibly think of in order to get a specific given number. for the open problem presented in Figure 3.2 one possible combination could be $6 + 2$.

Constrained Problems

The second part consisted of 5 items was created by the researcher and inspired from the Number Navigation Game.

Figure 3.3: Sample Constrained Problem From the Pretest Questionnaire

2. Does the equation ((7 · 11 + 3) : 4) · 5 = 110 hold?

a. Yes

b. No

Figure 3.4: Sample Multiple-choice Equation Problem From the Pretest Questionnaire

In the constrained problems (see the figure 3.3) the participants were asked to start from a given number and get to a target number, using specific operations and numbers.

For example, let us say that the starting number is 76, the target number is 6, the allowed number are 1,3,4, and the allowed operations are subtraction and division (pre-test, item 2). A possible solution, obviously not the only one, could be $76/4 = 19 - 1 = 18/3 = 6$. The main idea behind the use of these problems was to test the participants precisely in the kind of task that the NN game was supposed to teach them. In the game the participant controls a ship and from a starting point wants to get to a target point where he will find the reward (in the form of a building block material for his city). It was expected that the participants would perform better in the post-test constrained problems. A claim that was confirmed according to the results (see the result chapter).

Multi - Choice & Fill - in Problems

This was the last set of problems of the Questionnaire and it was comprised of 2 parts:

The multiple-choice problems (8 items) and the fill-in equations problems (4 items). It was inspired by the work of the Finnish Team, the problems however, were adjusted in an appropriate manner to the level of expertise of the participants of the present study.

The multiple-choice problems were divided into 2 subcategories

1) the conceptual problems (4 items), where a question e.g. "does the equality in $(7 * 11 + 3) : 4 * 5 = 110$ holds true or not" (see figure 3.4) was given to the participant and he/she had to circle the answer he thought was right. In this example the equality either is correct or not so there are 2 possible answers.

2) The equalities where the participants were expected to select from 4 possible choices the right one in order for the equality to be correct (see the Figure 3.5)

Finally, the last part of this set of problems was the fill-in equalities where the participants were expected to complete equalities by filling in the appropriate number in order for the equality to hold true(for an example, see Figure 3.6).

D. $(16 \cdot 7) : 2 + 8 =$ ___ $: 4$

a. 240
b. 256
c. 264
d. 244

Figure 3.5: Sample Fill-in equation Problem From the Pretest Questionnaire

A. $13 \cdot 9 = 234 :$ ___

Figure 3.6: Sample Fill-in equation Problem From the Pretest Questionnaire

3.5.2 Demographics Questionnaire

The participants were also asked to fill-in a questionnaire with demographic information in order to get a clear view of the characteristics of this research's sample. Almost every participant finished the questionnaire in 1-2 minutes.

The Demographics Questionnaire sheet can be seen in figure 10.14 in the Appendix B1.

In the questionnaire there were the typical questions about genre, age, education degree and some more sample specific questions like years of experience in education, computer skills, video game playing, and a characterization of their teaching method.

Let us observe the items under a magnifying lens:

The genre item was a standard item having two choices, male or female.

The age item followed the Prenskian classification of Digital Natives (1980- today) to Digital Immigrants (1979 and before) bearing always in mind the Greek reality (Greece always follows the technological innovations with a decade lag/latency).

The education degree item included 3 alternatives: *i*) Bachelor Degree (4 years, one year more than predicted by the Bologna declaration); *ii*) Master's Degree or post-graduate student (since some of the participants have not yet obtained their master's in Math Education) and *iii*) Doctor of Philosophy Diploma (Phd).

The Experience in Education item had three alternatives: *i*) more than two years of experience and teaching, *ii*) more than six years and *iii*) more than 10 years.

The Computer skills item had three choices *i*) Proficient user (frequent),*ii*) Novice user (infrequent) and *iii*) No user . The choices were partly inspired from Kebritchi's et al work[43].

The Video-game playing frequency item consisted of three possible choices *i*) 3+ times/week,*ii*) 1-3 times/week and *iii*) 0 times/week. The choices as before were partly inspired from Kebritchi's et al work[43].

Last but not least the teaching method item was a 5-likert scale one, in which on the left side was the teacher-centered instruction and on the right side was the student-centered instruction. The participants had to pick a number that would characterize their teaching practice. The item stems from Kebritchi's et al work[43] and aims to help the researcher in understanding each participant educational practice in order to evaluate their attitudes in a better, more informed way.

The main idea for the inclusion of the following items was firstly to establish the quality of the sample and secondly to get their experience in the education field, their computer skills, their video game playing history and their teaching method in order to have more

information and better understand and evaluate their open-ended questionnaire answers.

3.5.3 Open-ended Questionnaire

The open-ended questionnaire (hereafter OEQ) comprised of three main modules. The first was a set of four questions on *Mental Calculations*. The second consisted of six question on beliefs and attitudes about *Video Games in Education*. Finally, the third consisted of 11 questions on the *Number Navigation Game*.

The participants were administered the questionnaire in the form of a digital file (in $MicrosoftWord^{©}$ (see Appendix B3 figure 10.13) and they had to respond in digitally written text.

The questions of the questionnaire were given in an open form and the participants were instructed not to answer the questions with isolated one-word-sentences.

The researcher was present during the whole process. He made necessary clarifications, either on the terms used (e.g., mental calculations) or on the intended meaning of the questions.

This procedure was followed mainly for 2 reasons. Firstly due to time limitations and secondly due to workload limitations.

One more think that i want to highlight in the OEQ procedure was that the questionnaires were written and filled in Greek, the native language of the participants. The answers of the participants have been translated by the researcher, who have made the necessary conversion in the language expressions, of course bearing always in mind the participants viewpoint and the general idea that she/he wants to convey, in order to achieve an understandable translation from Greek to English.

3.5.4 Gaming Sessions

The gaming session lasted two hours, during which the participants had to play the Number Navigation game (hereafter NN). There was no specific goal, that is, they did not have to play in order to complete X number of levels or earn X number of gold medals etc. The participants-players were free to navigate through the electronic seas of the game and browse the gaming content of the levels without any specific order. It was given to them as a sandbox activity to talk in gaming nomenclature (i.e. terminology). This decision was made following the pilot study.

Another decision, concerning the gaming sessions, that stems from the results of the pilot study was to give the participants a modified version of the game. Given the background of this population, I reasoned that they should start from a higher level of difficulty. Thus in the game version given to the participants, the first and second levels had been completed and therefore the players would start from the third level. The starting screen of the game presented to the participants in contrast to the initial starting screen of the Finnish Team can be seen in Figure 3.7.

A 10-15 minute break after 1h of game-playing was offered to the participants if they'd like to use it. This recess was totally optional, some of the participants needed and made use of it while others kept playing until the end of the gaming session.

It is also reported that in some stages of the game, especially in the energy mode where the game got more difficult, the players had to stop playing, work offline the gaming platform for a while and reflect on what the best and most efficient road would be.

Figure 3.7: Initial Starting Screen and Second Level Starting Screen of NNG

The gaming sessions logfiles from each participant, indicating their time on the game, their gaming scores, and their exact moves in the game were collected, archived and transcribed into text files.

The initial idea was to analyze the log files and try to examine the number paths that the participants would follow e.g. would they find a some standard calculations and build on them to make their next moves or would they do something else and also monitor their playing styles and their in-game pattern recognition. After extensive discussion with the advisor of the thesis it was decided that to include a game log analysis would greatly exceed the aims of this study.

During the gaming sessions i worked as a facilitator who answered questions, gave feedback between moves, prompted for explanations and gave praise or encouragement to keep subjects confidence high.

4

Results & Discussion I - Quantitative

The presentation of the results will be two-folded. In this Chapter the quantitative results from the pre and post tests, Demographics Questionnaire and the Gaming Session will be displayed and in next chapter the qualitative results from the open-ended questionnaires will follow.

4.0.5 Demographics Coding and Results

The answers to the demographics questionnaire have been coded using numbers in order to be easily manipulated through Excel. For the *gender* of the participants zero has been assigned to women (0) and one (1) to men. Concerning the *Age Group* of the participants zero has been assigned to those that were born before 1980 (unbounded) and 1 to those that were born from 1980 until today.

As for the *education degree* three choices were given: zero was assigned to Bachelor degree, one to Master degree and two to Phd degree. Here i want to comment that the choices in this question were somewhat platitudinous and i am saying this because all the participants were selected with the criterion to be post-graduate students.

Regarding the participant's *experience in education* the categorization was three-folded; zero was assigned to over than 2 years experience, one for over 6 years of experience and 2 for over 10 years of experience in the field of education.

In the *computer skills* of the participants question, zero has been assigned to those that did not use a PC, one was assigned to novice users and two to proficient users.

For the *video games use-experience* question zero was assigned to those participants that played no video games in a week's time, one to those that played from 1 to 3 times per week a VG and two to those that played VG more that 3 times/week.

Finally their *educational practice* as it had been mentioned in the demographics section of methodology was evaluated in a 5 likert scale item with 1 being the Teacher-center approach and 5 being the Student-center approach.

The coding of the demographics questionnaire is given in this section in order for the reader to understand the presentation of the results. The full table of the demographics questionnaire answers is given in Appendix B1 in figure 8.1.

4.1 Pre/Post Test Analysis and Results

The quantitative analysis of the pre and post test data will be presented in this section.

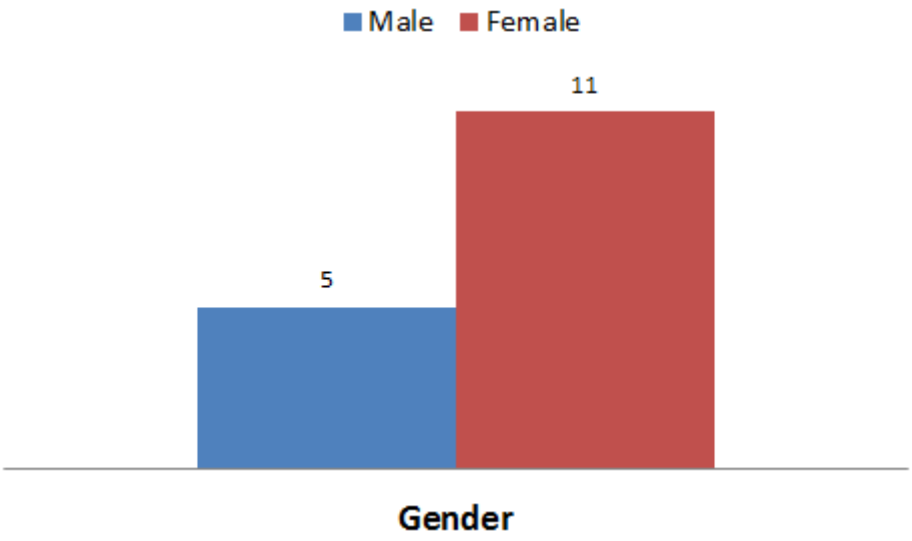


Figure 4.1: Gender

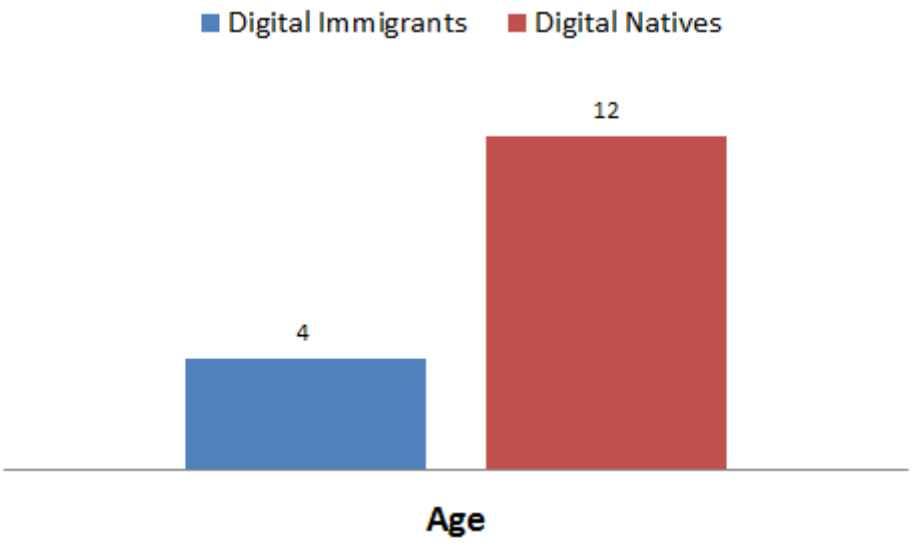


Figure 4.2: Age

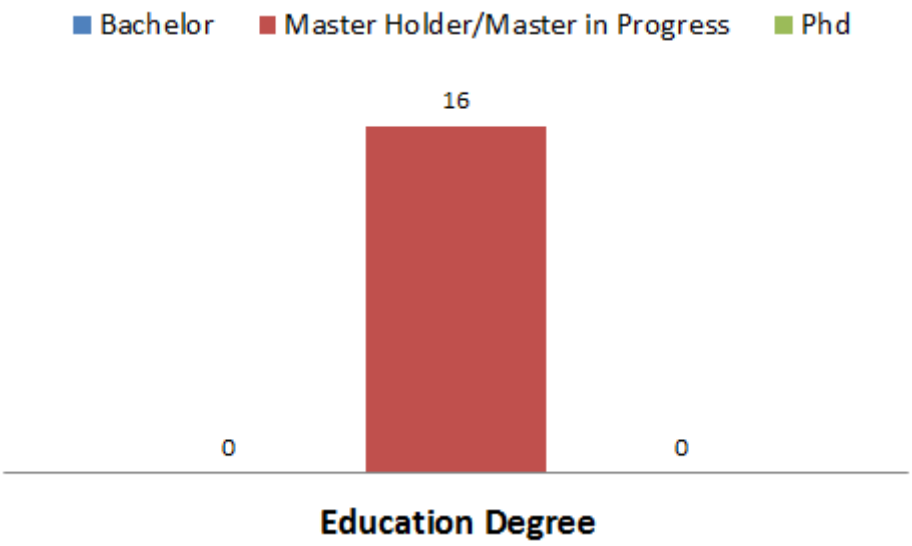


Figure 4.3: Education Degree

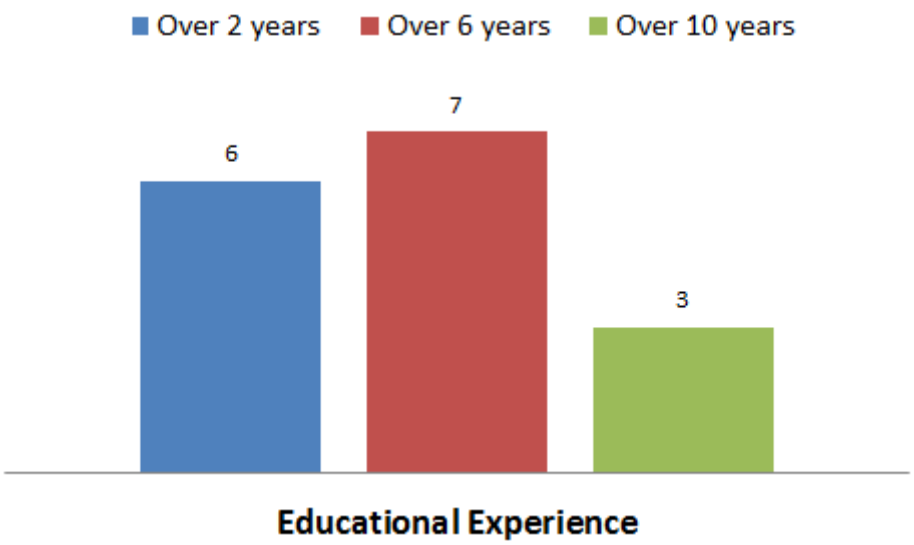


Figure 4.4: Gender

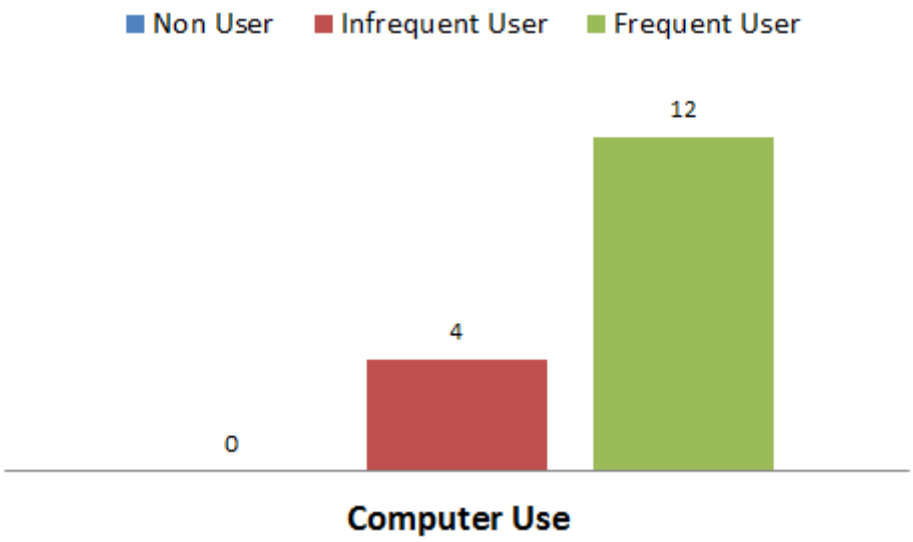


Figure 4.5: PC Use

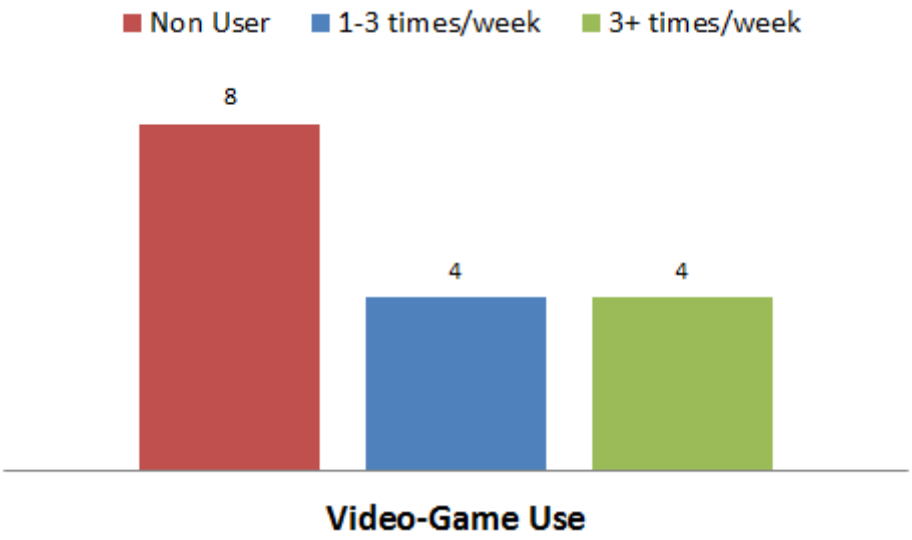


Figure 4.6: Video-Games Use

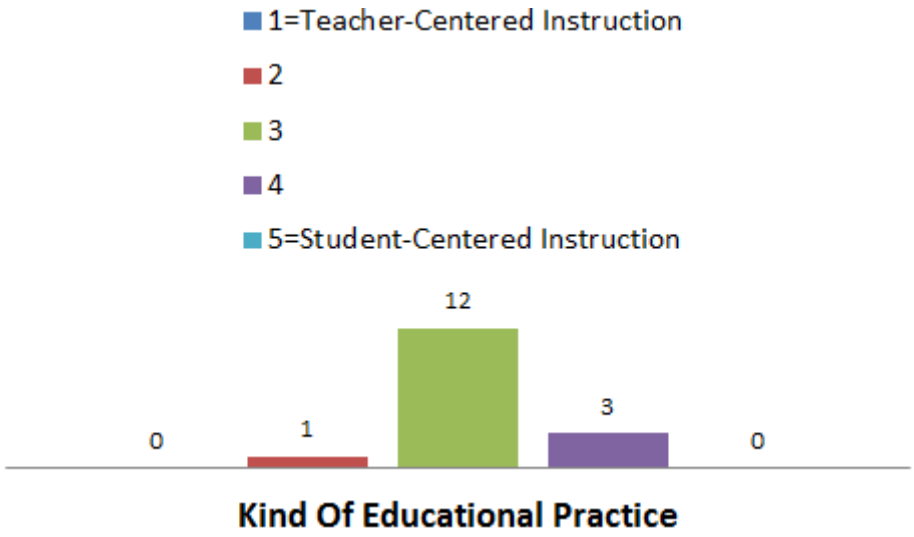


Figure 4.7: Educational Practice

Exclusion of Two Participants

The sample to be analyzed has the characteristics that i have mentioned in the corresponding section but with a modification. After reflection on the results i have decided to exclude two participants from the quantitative results i.e. one participant (participant N^o4) that played the game for three and a half hours (210 minutes, straight) and one participant (participant N^o9) that played the game for almost 3 hours (170 minutes straight). These participant created a discontinuity in the results, having played longer the game and could constitute grounds for ambiguity in the quantitative analysis. So the effective sample of this study would be 14 participants with the characteristics that have extensively been described in the demographics section.

Concerning the demographics of the participants: Their gender was male for participant N^o4 and female for N^o9, they were mathematics majors, N^o4 a digital immigrant and N^o9 a digital native, following the prenskian classification. Regarding their educational experience N^o4 had taught over 6 years and the N^o9 over two years. They were both infrequent computer users and concerning their video game experience N^o4 had none and N^o9 was a light VG user.

To justify the attitude of the participants it would suffice to highlight their motivation. Specifically participant N^o4 wouldn't stop to play the gave before he finished the second level's stages, a sort of obsessive compulsive behavior if i am allowed to use the medical terminology, and to add to this he got disappointed when he finished the second level's stages to see that the third level's stages got unlocked. Participant N^o9 was motivated in a more enthusiastic way, playing the game for as much as she could until she had to stop to go to her work.

They were two special cases not only judging them from this behavior but also have seen their open-ended questionnaires and by knowing them in real life.

Coding

The results of the analysis of Pre and Post Test of the participants will be presented briefly and to the point in this section and for reference in the Appendix B1 i will give them in their full form. The analysis of the Pre and Post test has been done using

IBM's SPSS©(hereafter SPSS) and Microsoft Excel©(hereafter Excel). Excel was used especially for graph creation.

For research ethics reasons the names of the participants are not presented and have been replaced by the participant's number. The participants that have been excluded from the results, as it had been said before, are participants N^o4 and N^o9.

The items from pre and post tests have been represented in a specific way which is followed also in the presentation of the full results in the Appendix B1 chapter. Hence writing PreOpenx i mean the x-item of the open set of problems of the pre-test (e.g. saying PreOpen3 means the third problem of the open problems of the Pre-test). Similarly PreConx signifies the x-item of the Constrained problem set of the pre-test and PreMultix the x-item of the Multiple choice problem set of the pre-test. In the similar way we interpret the "acronyms": PostOpenx, PostConx and PostMultix.

The Pre and Post tests were evaluated according to the following rubric:

a. ***Open Problems***

The open problems were graded according to the algorithm that is described extensively below. Then the 4 items of the open problem set, from pre and post test respectively, were summed up in order to make an aggregated score. These sums have been named PreOpenTotal and PostOpenTotal accordingly.

Open Problems Algorithm

The participants answers in these questions were graded following the algorithm below that was constructed partly from Lehtinen's team and partly by the researcher in order to examine the some specific aspects that was believed would change from pre to post test.

So the algorithm is:

$$\begin{aligned} GradeofOpenItem_i \; = & \\ & correct \; + \; number\ of\ combinations \; + \\ & number\ of\ different\ numbers \; + \; number\ of\ operations \end{aligned} \tag{4.1}$$

Lets examine the parts that consist the algorithm:

1) **Correct**

   If the participant has found at least one mathematically correct combination he/she is awarded 1 point.

2) **Number of Combinations**

   The participant is awarded half a point for finding 0-2 mathematically correct combinations and another 0.5 if he has found 3 and more. The idea behind this concept was to pick the participants with more than the average combinations and award them the full grade - a way to pick out those participants who scored more quantitatively if you will.

3) **Number of Different Numbers** This criterion and the next one have been set in order to observe any qualitatively change, if at least there was any, in the mindset of the participants from pre to post test which would be mirrored from their answers. Thus the participant is awarded a full point if he has at least one combination with 3 or more different numbers. For example to get 8 one could think $42/14 + 6 - 1 = 8$ in order to get the 1 point. The basic concept behind this grading categorization was to differentiate the participants who made more complicated and complex combinations.

4) **Number of Different Operations** The last criterion was set also, as it is mentioned above, in order to examine the qualitative changes in the mindset of the participants if they were any.

   The participant was awarded half a point if he had in at least one combination 2 or more different operations if those were addition or subtraction and the other half point if in at least had found a combination with 2 or more different operations if those were multiplication or division. To clear the fog out i am giving 3 examples *i*) $6+2$ was awarded 0 points because it only included one operation (i.e. addition) *ii*) $14-6-1+1$ was awarded 0.5 points because it includes 3 operations (2 different) but only addition and subtraction *iii*) $42/14 + 6 - 1 = 8$ was awarded 1 point (the full score) as it included 3 different operations one of them was division (0.5 points) and the other 2 was subtraction and multiplication (0.5 points).

   The full score for an item was 4 points and for the whole open problem set, bearing in mind that there were 4 items, was 16 points. Hence if a participants achieved x,y,z and w points accordingly in each of the 4 items of the open problem set his total score would be $x + y + z + w/16$.

   The basic concept behind this grading categorization, as it was mentioned above, was to differentiate the participants who made more complicated and complex combinations.

b. ***Constrained Problems***

The constrained problems were graded either as right or as wrong. So their categorization was binary, i.e. if the participant had a correct answer in the respective item he would be awarded 1 point if not zero points. The constrained problems set constituted of 5 items, for pre and post test in correspondence, thus the full score that a participant could take in this section would be $x/5$. Where x would be the sum of the scores of the participant in each of the five, constrained item. These sums have been named PreConTotal and PostConTotal accordingly.

c. ***Multiple Choice & Fill in Problems***

In the same manner the problems of this section were graded either as right or as wrong. In the case that the participant's answer was right i awarded 1 point for the respective item and if he/she was wrong i would award zero points (also a binary categorization).

The problem set comprised of 12 items, for the pre and post test alike. Hence the full score that a participant could get was $y/12$. Where y would be the sum of the scores of the participant in each of the twelve items of this section. In the same fashion as above these sums are named PreMultiTotal and PostMultiTotal accordingly.

Last but not least there is a field in the data sheets which are presented in the Appendix B1 that is entitled, Extra Time. This field concerns only the Pre and Post Constrained

and Multi-Choice & Fill-in problem sets and not the open problem sets where from the research design the participants had to use all of their available time. Ergo the extra time i.e. the time that had remained to the participants that had completed the respective pre/post test section earlier than the defined time, if any, was written in the extra time field of the results.

4.1.1 Results

Having graded the constitutional parts of the pre and post test there was a need for an aggregated score for the whole test. This need was cover by an ad lib score that was created by adding the PreOpenTotal, PreConTotal and PreMultiTotal (PostOpenTotal, PostConTotal and PostMultiTotal correspondingly) for each participant.

The problem though was that a common measure was needed in order to try and compare the pre test total results to those of the post test total. Certainly, some sort of adaptation of the results to a common measure was due in order to claim some sort of comparison. Therefore i decided to set a common measure in the PreOpenTotal, PreConTotal and PreMultiTotal (PostOpenTotal, PostConTotal and PostMultiTotal correspondingly) by creating their analogous versions i.e. PreOpenTotalAdapted, PreConTotalAdapted and so on in order to construct the Pre/Post(Total)Adapted scores.

For this procedure the least common multiple of the full scores in Open, Constrained and Multi problem sets was found in order to avoid high digit decimal numbers. Hence the simplest way i could think of to avoid that, was use the least common multiple.

Consequently the full score in the Open problem set was 16, the full score in the Constrained problem set was 5 and the full score in Multi&Fill-in problem set was 12. The least common multiple of those numbers happens to be 240 so each of the Pre/Post(Open,Con,Multi)Total had to be adapted to 240. This could easily be done by using the simple rule of three. For example to adapt the PreOpenTotal score of the nth participant you had to multiply the PreOpenTotal score with 240 and then divide it with 16 i.e. $PreOpenTotal * 240/16$.

This procedure had to bee done analogously for Constrained problems and Multi&Fill-in Problems changing only the division from 16 to 5 and 12 respectively. Following the rubric that has been described, i have filled the matrices with the results and they are shown in the Appendix B1.

Hence by this procedure the Pre/Post(Open,Con,Multi)TotalAdapted scores have been generated.

By the same token the PreTotal and PostTotal scores were calculated adding up the pre/post(..)total scores e.g.

$$PreTotal = PreOpenTotal + PreConTotal + PreMultiTotal$$

The analogous procedure was followed to calculate the PostTotal scores.

And thus the adaptation of the above scores had to follow the same procedure in order to have scores suitable for comparison with the SPSS's tests (paired t-test, paired wilcoxon etc). Hence PreTotalAdapted and PostTotalAdapted were calculated adding up the respective scores, e.g.

$$\begin{aligned} &PostTotalAdapted = \\ &PostOpenTotalAdapted + PostConTotalAdapted + PostMultiTotalAdapted \end{aligned} \tag{4.2}$$

Equivalently for PreTotalAdapted.

Comparing Pre and Post Test Results

To compare if there was significant differences in the results of post tests from those of the pre test two things had to be done:

i) First to examine the correlation between pre and post test i.e. to examine if i was comparing things that could be compared and *ii*) second to use specific tests like paired t-test and paired wilcoxon in order to examine whether the differences between pre and post tests were statistically significant, if in fact there were any.

Examining the PreTotalAdapted with PostTotalAdapted scores for the sample of 14 individuals there was no statistical significant correlation to be found and thus i couldn't perform the non-parametric test, specifically Wilcoxon matched-pairs signed ranks test. Something a tad weird because from the means and the min-max range it could be seen that the participants in general improved their scores.

Observing closely the results i found that there were two participants who had lower scores from pre to post test and when excluded the PreTotalAdapted and PostTotalAdapted scores were not only correlated with a significant correlation but also that Wilcoxon test could be conducted finding statistically significant differences. Indeed cross-checking their behavior throughout the session through my field notes and their answers in the open-ended questionnaires where they had commented about their fatigue and after reflection and discussion with my advisor we decided to exclude them. The participants that were dropped were N^o12 and N^o13.

In general i believe that this study's results could show a bigger improvement in the sample had i taken into account some "flaws" in the design which were necessitated due to limitations (time, work, framework of the study i.e. it was a master thesis study) and to which i attribute the exclusion of the four participants in total from the quantitative part of the results. Those design flaws range from pre/post test creation to the single session (4-5 hours) which resulted in fatigue of the participants and also the game session duration (2 hours) which could be a bit longer if was broken in parts.

Having said that i, now, continue to the part of the analysis. Ergo now comparing the PreTotalAdapted with PostTotalAdapted scores using the Biviriate Correlation tests of SPSS, specifically Pearson, Kendall and Spearman correlation i found that there was indeed a positive correlation. The results following the APA style for were $\tau = .545$, $n = 12$, $p = .014$ (kendall's tau) , $r_s = .713$, $n = 12$, $p = .009$ (spearman's rho) and $r = 0.786$, $n = 12$, $p = 0.002$ (pearson coefficient). Obviously the significance probability (sig) i.e. the p-value was smaller than .05 thus suggesting that the correlation is significant. The application of the above correlation tests indicates that there is a moderate to good positive correlation between PreTotalAdapted and PostTotalAdapted scores, hence we are allowed to apply the non-parametric test.

Having a small sample i couldn't assume a normal distribution so the non-parametric tests (i.e. paired t-test) were ruled out. As there were two scores in two specific time points (before and after gaming session) for each participant it was apparent that the Wilcoxon matched pairs signed rank test had to be used in order to assess whether there were differences between the pre and post scores.

So applying the Wilcoxon matched pairs signed rank test the results were found to be $T = 3.059$, $p = .002$. The p-value being $< .05$ suggests that we can reject the null hypothesis H_0 : the median difference between the pairs is zero and thus accept the alternative hypothesis H_A : the median difference is not zero. Hence concluding that

	OpenTotal		ConTotal		MultiTotal		Total_Adapted	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Average	11,46	11,71	2,17	3,67	7,00	9,75	415,88	546,63
Min	8,00	6,50	0,00	2,00	5,00	3,00	235,00	339,00
Max	15,00	16,00	5,00	5,00	11,00	12,00	547,50	685,00
SD	2,12	2,94	1,47	0,98	1,81	2,38	83,70	92,57

Figure 4.8: Mean Scores of The Comprising Parts of Pre & Post Tests

	Correct Answers		Number of Combinations		Multi Different Numbers		Multi Operation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Average	3,75	3,46	2,08	2,17	3,58	2,42	3,00	2,71
Min	2,00	2,00	1,00	0,00	2,00	1,00	2,00	1,50
Max	4,00	4,00	4,00	3,00	4,00	4,00	4,00	4,00
SD	0,62	0,69	0,90	0,83	0,67	0,85	0,85	0,92

Figure 4.9: Mean Scores of The Comprising Parts of Open Items

there is a significant difference between PreTotalAdapted and PostTotalAdapted scores, of the participants that improved their scores (the current sample of 12 participants after excluding 4 participants for the reasons explained above).

Of course there is an issue, as i briefly mentioned before, that i want to highlight which is the absence of a control group. If such a group existed we could speak of some form of a generalization to populations with the same characteristics as the one described in this study. Discussing this with the supervisor of the study we concluded that it may not hold much value to try to generalize the specific results of a specific game i.e. Number Navigation, of a specific population i.e. highly experienced, interested in education and mathematically-versed following a specific methodology to other populations that have the same or similar characteristics. So we decided not to include such a control group. This decision was also based to time and workload limitations and also to sample constrains (i.e. the sample was unique if you will allow me the expression and thus it was not easy, at least not in this study's framework, to find an equivalent control group).

In Figure 4.8 you can examine the descriptive statistics data for the pre & post Open, Constrained, Multi and TotalAdapted scores (i.e. means, max, min and standard deviations).

The full results are presented in SPSS' output in Appendix B2.

Furthermore concerning the open problem module i attempted to make an evaluation in the steps of the work of the Finnish team. Thus according to the algorithm that was created for the open problems the corresponding scores for each evaluation factor, i.e. pre/post correct, pre/post number of combinations, pre/post multi-different numbers and pre/post multi-operation scores for each participant.

In Figure 4.9 you can examine the descriptive statistics data concerning the comprising parts of the evaluation of Open Items which has been described with the algorithm above (i.e. means, max, min and standard deviations).

	Gold Medals	Silver Medals	Bronze Medals
Average	7,00	1,67	0,75
Min	2,00	0,00	0,00
Max	12,00	4,00	2,00
SD	3,44	1,30	0,87

Figure 4.10: Mean Scores of Medal Performance

4.2 Gaming Sessions Results

The data that the game stored for each participant, i.e. the log files and the save-games files, have been acquired and recorded in order to be presented in this section. For an extensive illustration of the recorded data you can see figure 8.8 in the Appendix B1.

The participants played the 2nd level's stages and by this i mean that the zero and first level stages were unlocked and are not being count in the sum of the stages that the participants completed. The second level, as it has been mentioned in the NNG chapter, consisted of 20 stages which was also the unsaid goal of the gaming session. Of course it was not expected from the participants to complete all of those 20 stages, it was an "unreachable" target, at least for somebody who played the game for the first time and in the duration of 2 hours. The average map completion in the gaming session's time was 9.41 stages. The most productive participant completed 14 stages and the least productive 5, having the rest of the participants variate in between these extremes.

As it can be seen in the figure 8.8 which lies in Appendix B1 the participants that have completed 5,6 and 7 stages have played more energy stages (i.e. everybody has played a number of energy stages greater than half of the total stages, e.g. 5 stages 3 energy levels) and struggled with the optimal route concept. Most of them weren't happy with a lower than the gold medal, restarting the same level over and over again in order to achieve it.

In general though the average energy map completion was lower than the average moves map completion. Indeed, the average energy map completion was 4.20 stages in contrast to 5.25 stages for the moves maps. The most productive participants completed 6 energy stages and 10 motion stages (not the same participant) while the least productive completed 3 energy stages and 2 motion stages.

Concerning the in-game medal acquisition the participants unanimously targeted the gold medal. The average gold medal acquisition was 7 contrasting the average silver medal acquisition which was 1.7 and the average bronze medal acquisition which was 0.75. The most productive participants got 13 gold medals the least productive of them earned 2 of them.

Game Performance Indexes

In order to better evaluate the game performance of the participants and being based on the results and analysis of Brezovszky [10] i have created a gaming quality index (to which i will also refer as Gaming Performance Index-Medals) measured in terms of number and type of medals collected by the player.

Gold, Silver and Bronze medals were given specific values in order for this game performance evaluation to take place. The gold medals were evaluated to worth twice as

	Gaming Performace Index Medals	Gaming Performace Index Stages
Average	32,08	13,58
Min	15,00	10,00
Max	50,00	19,00
SD	12,27	3,00

Figure 4.11: Mean Scores of Gaming Quality Indexes

much as silver medals and silver medals were evaluated to worth twice as much as bronze medals. The sum score was created by calculating the number of gold medals multiplied by 4 plus the number of silver medals multiplied by 2 plus the number of bronze medals.

$$Gaming\ Quality\ Index\ = \\ 4 * GoldMedals + 2 * Silver\ Medals + Bronze\ Medals \quad (4.3)$$

The maximum value that the gaming quality index could take was 20 $stages * 4 = 80$.

Extending the concept of this gaming quality index and in an attempt to turn into benefit the full potential of my data i am incorporating the map completion index (to which i will refer also as gaming performance index-stages) as an additional index in order to assess game performance.

Having played the game for over 15 hours and by the knowledge that i have got from my field notes during observation of the participants playing the game i would say that, roughly speaking, an energy level took at least double the time and effort for a participant than a moves level did.

Therefore the decision was easy: an energy completed stage would worth twice as much as a moves completed stage. Consequently to incorporate the mode of each stage that the participants had completed i 've created the corresponding index following the algorithm below.

$$Map\ Completion\ Index\ = \\ Number\ of\ Completed\ Energy\ Stages + Number\ of\ Completed\ Moves\ Stages \quad (4.4)$$

The maximum value that the map completion index could take was $11 * 2 + 9 = 31$. To clarify this let me say that there was 11 energy stages in the second level and 9 moves stages.

You can observe in Figures 4.10 and 4.11 the descriptive statistics data concerning the Medal Performance and the Gaming Quality Indexes (i.e. means, max, min and standard deviations)

Preference of Gaming Mode

Studying the data, produced by the gaming session, that concern the map completion and specifically how many energy or moves stages did each participant complete and also their finishing screenshots that are presented in the Appendix D, i have observed

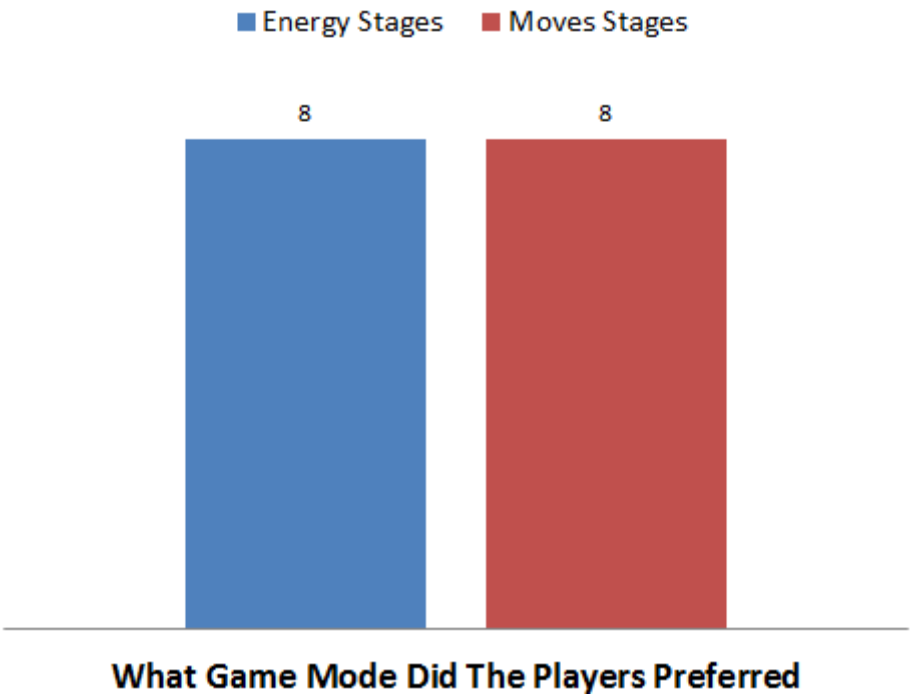


Figure 4.12: Preference of Gaming Mode

that the participants where divided, i.e. 8 participants, played more moves stages and 8 participants played more energy stages.

The comparison of the completed, by the participants, stages was carried out with a simple IF function in Microsoft Excel.

A representation of the results can be seen in figure 4.12 and for the full version of the above results you can look figure 8.9 in Appendix B1.

According to the above results i cannot claim any clear particular preference of the participants over energy or moves mode. One thing that emerges though is a dual categorization i.e. those who preferred energy over moves mode and those who did the opposite.

Having said that i would also like to add here that there was a number of participants who reported that they wanted to play at first the moves levels which were easier and then go to energy levels, in an attempt to play the game through a scaling difficulty (the specific number was 3-5 participants and i am giving a range value here because the criteria of this observation were subjective[field notes, and personal observations] unless the participants explicitly declared it).

The majority of the participants i.e. 93.75% (all but one participant) though, as it can be seen in the open-ended question concerning difficulty in the next section of this chapter, found the game to be normal to easy.

So if we "invalidate" the participants that had this "scaling difficulty obsession" then we can see that a majority of the participants did choose energy mode over moves mode which they found more trivial.

The assertion i want to make here is that the more qualified (mathematically) the sample under testing would be the more they would choose energy stages over moves stages for reasons of the triviality of moves mode over the energy mode.

Last but not least you can observe in the Figure 4.13 the descriptive statistics data concerning the Mode of Preference (i.e. means, max, min and standard deviations).

	Energy Stages	Moves Stages	Total Stages
Average	4,17	5,25	9,42
Min	3,00	2,00	6,00
Max	6,00	9,00	14,00
SD	0,83	2,99	2,87

Figure 4.13: Mean Scores of Mode Preference

I want to highlight one more thing that i consider to be a methodological flaw in the design of the study. Four of the participants asked for pencil and paper to make calculations there while playing the game. Having extensively thought about this practice i can say that it had no difference than giving the participants a calculator.

The subject matter here was that the participants should not exercise their algorithmic calculations skills which they obviously had, being high skilled mathematicians. What mattered was to make them try and think mentally how to make calculations and if the could modify their ways or invent new ones in order to achieve efficiency.

5

Results & Discussion II - Qualitative

5.1 Open-ended Questionnaire Analysis

As it has been mentioned above in the methodology chapter the open-ended questionnaire were conducted in a digital form. A specific categorization in almost every question of the questionnaire has been made according to the answers that the participants gave in order to interpret them better.

The results are going to be presented in accordance to the following rubric: *i*) writing the percentages for the categories that have emerged for each question, *ii*) depicting of the categories in a graph, *iii*) quoting the answers of the participants that worth to be remarked/noted and *iv*) reflecting on each question.

Skill in Mental Calculations

The open-ended questionnaire started with the Mental Calculations(thereafter MC) module, as it has been mentioned in the OEQ section on the Methodology chapter, and the first question was *"Do you think that you are good in mental calculations? If yes why? If not why? Elaborate."*. The majority of the participants, 56.25%, considered themselves poor in MC, 18.75% thought they were mediocre and 25% believed that they were actually good in this mental procedure. You can see figure 5.1 for a depiction of the above percentages.

Some of the participants tried to explain why they thought were poor in MC with answers like "I've not been specifically trained" or "I always doubt my results", "I am very slow and often-times I get stuck in calculating with my mind which makes me slower" and "I've used from times to times some tricks to make calculations quickly but I have failed. I find it difficult to retain multiple numbers in my head and compose a sound result" to defensive answers like "I prefer paper and pencil calculations" and "why bother, when i can use a calculator" (defensive in the way that they don't even want to think something they may not be good at).

The participants that thought were average in MC remark comments like "I'm slow, my trick is to break calculations in smaller bits" and "it depends (if he/she is good in MC) on the hour of the day, the concentration etc. I've developed some strategies that help me in calculations".

Some of the participants who considered themselves good at MC commented that "when in my everyday life I ve got a calculation problem I do it mentally; that's why i am good" and "I ve got good memory and concentration when given a mental calculation...i

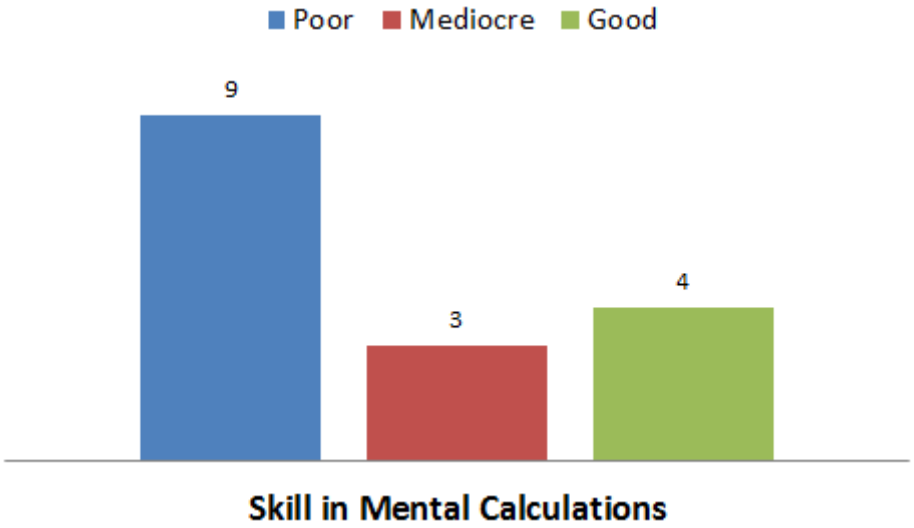


Figure 5.1: Reflection About Skill in Mental Calculations

have observed this in comparison with other people".

The main notion behind this question was to grasp the participants personal viewpoint on their skill in MC. It was not expected that most of the participants would though themselves as poor in MC and of course such a claim was not confirmed by the results in pre/post tests.

Importance of MC in Education

The second question that followed was *"Do you consider mental calculations important in the field of mathematics education?"*. Almost all participants, 93.75%, considered MC important for Mathematics Education and only 6.25% (1 participant) believed that MC were not significant. You can see figure 5.2 for a depiction of the above percentages.

Five of the participants that replied with yes in the above question posed some constrains for their positive answer like "MC are only important in elementary grades", "they are important but as a secondary task, they should not be an end in themselves.", "they are important only at a basic level, students should not be instructed to do long and difficult calculations", "they are an essential skill but we should not over-concentrate to them", "they are important only as brain-training and number strategic algorithms" and lastly "they are important but we should not get carried away, calculations are not the essence of math - they are only included in the essential skills that students should be good at. When students are good in calculations they can devote more time in the core, to math, procedure of solving math problems".

The proponents of MC remarked that "flexibility in mental calculations creates a specific mindset in mathematics education - a way of thinking about math If you will", "MC create positive attitudes towards math at least if you are good at them", "MC can help in drill and practice procedures", "MC provide strategies and reasoning to deal with math problems" and "a good relationship with MC indicates awareness of math structures and proper construction of mental images".

An idea that was intriguing was that "MC constitute a scaffold for higher math concepts" the participant elaborated in his open-ended answer that he meant this in the classical way i.e. that algebra is a generalization of arithmetic and calculus is the way that algebra behaves in infinitesimal numbers.

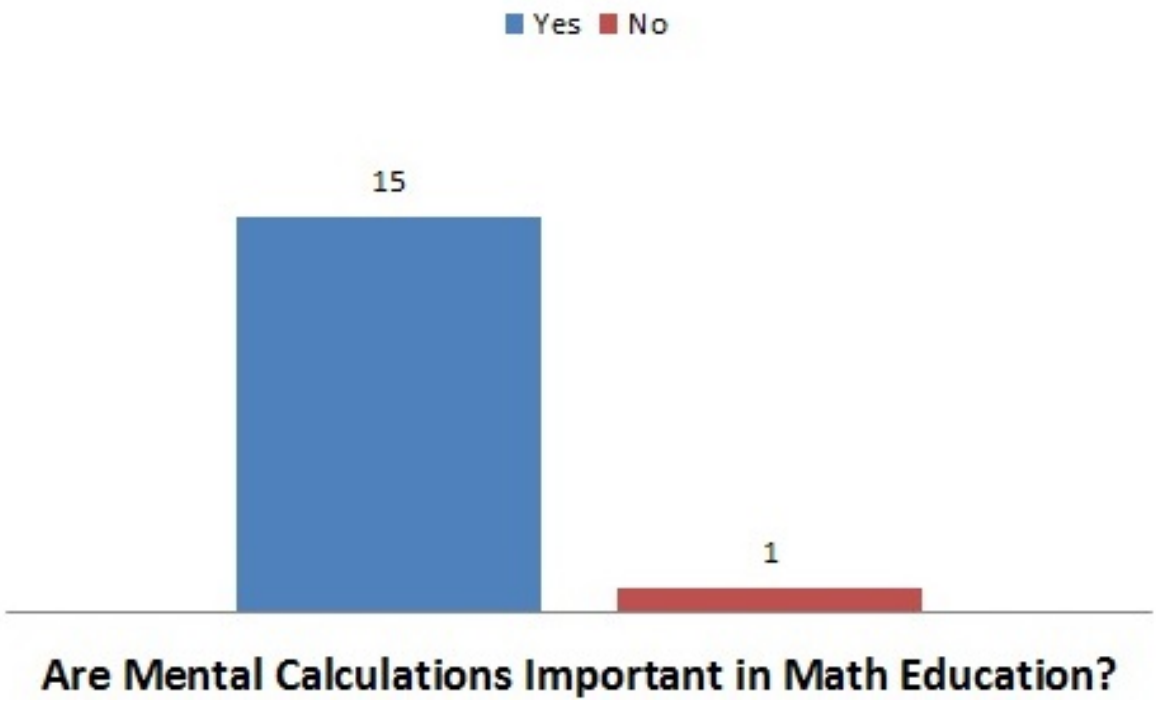


Figure 5.2: Importance of Mental Calculations in Mathematics Education

The participant who opposed to MC explained his stance saying "from personal experience I cant say that whoever comes sort in MC has also problems in math education. Beyond speed in arithmetics calculations i did never had problems in algebra, calculus and higher mathematics courses. Their main use, as i see it, is to get speed and train your brain in an algorithmic procedure". Here we have a participant who holds two master degrees in Math and Mathematics Education and has achieved this without any particular skill in MC as his answer in the open-ended question suggests.

The basic concept behind this question was to check if participants considered MC important for Mathematics Education and briefly explain their thesis. The majority of the participants considered MC's important in Math Education, something that was somewhat expected. The best feature of this question though was that each participant had to give a reasoning for his thesis and that some remarkable answers where given along the way.

Teaching Towards MC

The third question in MC module was *"In your classroom would/do you teach towards achieving a mental calculations skill? If yes how? "*. Most of the participants, 82.25%, had already taught or would teach towards MC skill acquisition and 18.75% opposed to the idea. You can see figure 5.3 for a depiction of the above percentages.

From the participants that alleged the idea of teaching to promote MC 3 of them set constrains e.g. "i would teach towards but i wouldn't go to great lengths" or "i would teach just basic stuff". One of those participants made a noteworthy comment in which he differentiated mental calculations from written calculations emphasizing differences in their core algorithmic procedure.

From the participants that opposed the idea one answered this way due to time and

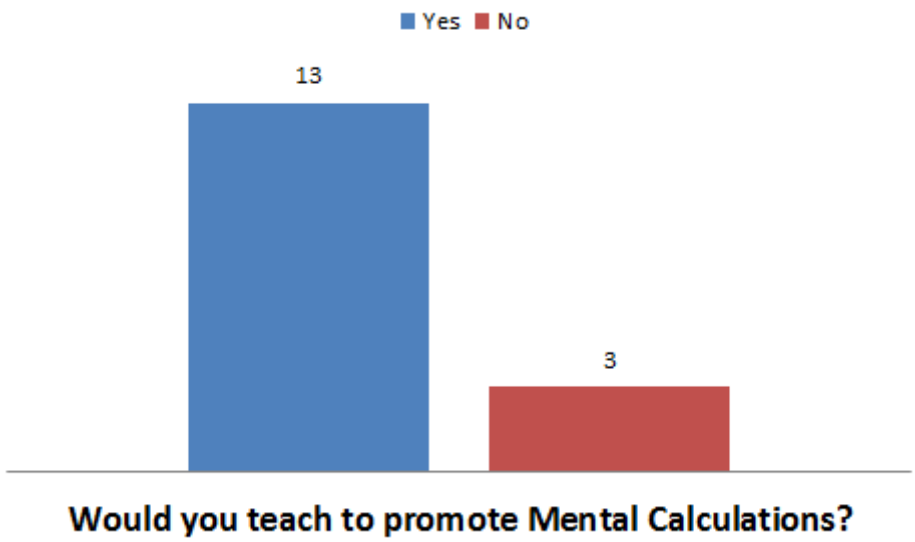


Figure 5.3: Teaching Toward Mental Calculations

curriculum constrains and another one questioned that MC are an integral part to mathematics and not just a set of rules.

The majority of the participants had very interesting remarks towards how they would achieve skill in MC: "i would apply think aloud protocol in order to examine their way of thinking and create a calculations method tank if you will...also accompany the student in doing aloud some difficult calculations", "magnitude conversion exercises could do the trick". One of the participants went a step further and proposed to use card games that include sums of numbers and maybe better Internet mini-games; "something like NN" as he says. Another participant commented that she would use tricks like rounding up $10and100$ etc for addition and subtraction but she couldn't think such rules for multiplication and division, maybe she says "because i have problems there myself".

One proposes "I would use exercises like give a starting number and demand the pupils to go to a target number bearing in mind that (make them imagine)they use a calculator were the addition button is broken". And another one went to the other side by saying that he would decree a ban on calculators. Finally many of the participants seem to agree that the students should figure out what strategy suits them better.

Something that is worth mentioning here is that the Greek Mathematics Curriculum does not include MC. The idea behind this question was to observe the disposition e.g. positive/negative of the participants towards teaching to promote MC and also to examine their ways of promoting the specific skill. Again here the great majority would teach to promote MC in their classroom, a result which was expected. It is very nice though to see the collective intelligence at work in such instances in the way of some noteworthy comments regarding how they were going to achieve that.

Promotion of MC by NN

The forth and last question of MC module was *"Would you say that NN promotes in an appropriate way mental calculations? If yes how? If no how? Elaborate."*. Almost unanimously, 93.75%, the participants agreed that the game promotes in a suitable way MC and only 6.25% (1 participant) though otherwise. You can see figure 5.4 for a

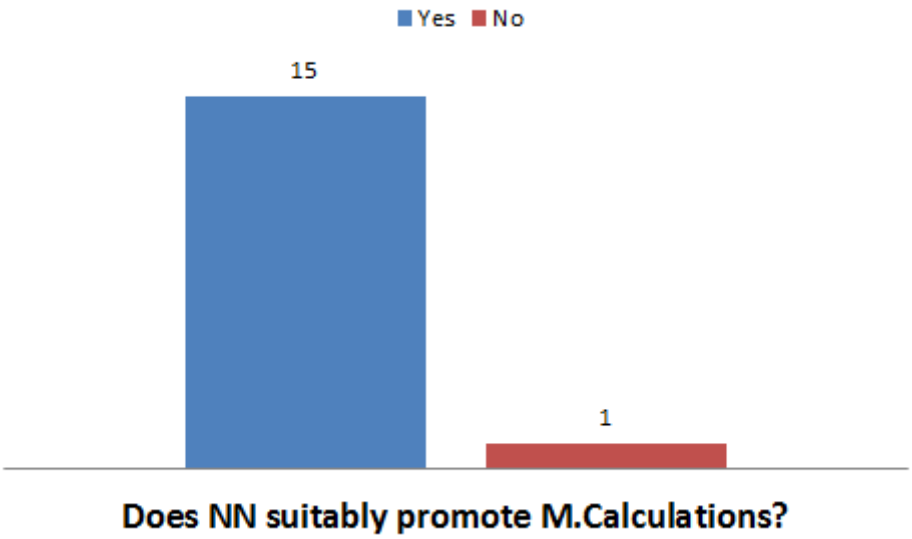


Figure 5.4: Promotion of Mental Calculations Through NNG

depiction of the above percentages.

From the participants that replied positively in this question, 5 of them posed some constrains. Let us hear them out: "the game could appropriately promote MC depending on the right context and implementation" or "under the right circumstances (here she means the grade in which the implementation will take place and having the essential equipment PC's etc.)" and "yes but at a basic level".

Another participant remarks that if the game is played in a periodic way then it could lose its initial appeal and become nothing more than drill and practice. The last comment i will refer to was that NN could certainly play a role but a student should strive in his own in order to become fluent MC.

The participants that advocated for NNG had some very cunning remarks about how the game promotes MC. One participants comments that "the nature of the game is to make "cost effective" decisions (here she means efficient calculations in order to conserve energy or movements) and also do reverse calculations changing them a bit in some levels due to the pirate feature which may contribute in the consolidation of the knowledge procedure". A supporter of the game states that it can help in the promotion of MC as it has attractive design which can motivate the students and also that the pirate and terrain restrictions features add points to the game-playing experience.

Two more positive, in the advocation that NNG promotes MC, participants reported: "of course the game promotes MC...it is based on making constant calculations.." and "with NN students can get familiar with mental calculation in a fun and subconscious way".

The following participant emphasizes that the promotion of MC from NN depends on the context of playing and on the targets that the teacher wants to accomplish; "Will the students going to play the game as a means to an end or as an end in itself" as he specifically asks. Here the participant, as i perceive it, wants to make a critique about the game that has been subtly mentioned in a question above. According to him the game should not fall down to be just a game of drill and practice.

The participant who replied negatively in the question remarks that "if the game is played many times it may help" but as he highlights he fails to see how this game can be

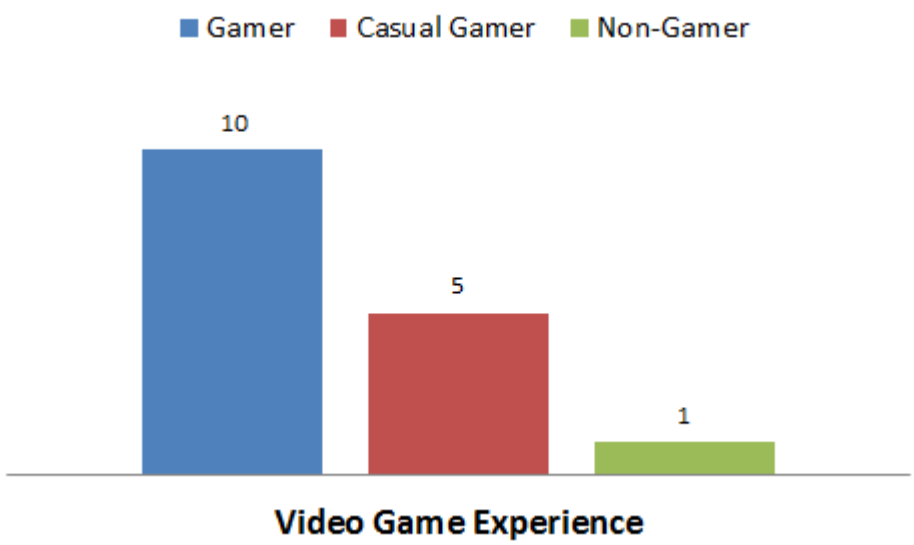


Figure 5.5: Video Game Experience

played many times, as after a while "it gets boring".

This question is an addition to the pilot study and has emerged through discussion with the Advisor. The main notion behind the question is to take a glimpse of the participants beliefs about the game's ability to promote MC, justified with the proper argumentation. It was obvious from my point of view that the answer would be unanimous, as one participant mentioned above: "Of course it promotes MC, all you do in the game is calculations". Concerning the verdict that the game suitably promoted MC i was a bit stunned, being myself a serious gamer.

Video Game Play

The next module of the open-ended questionnaire referred to the stances of the participants and their beliefs towards implementation of Video Games in Education, as it has been mentioned in the OEQ section on the Methodology chapter. The first question of the module was *"Have you ever played computer games? Elaborate!"*. According to the participants answers the following taxonomy has been made: *i*) *gamer*, 62.5% of the participants, *ii*) *casual gamer*, 31.25% and non-gamers with percentage 6.25% (i.e. 1 participant) . You can see figure 5.5 for a depiction of the above percentages.

Two of the participants where hardcore gamers, one playing from six years old and the other one playing video games systematically for over 20 years with an average of 2-3 games per annum as he quotes. The participants' video game playing choices cover a wide range of games categories. I am quoting some of the genres that they played: Strategy, sports, fighting, adventure, puzzle, escape games, mini and flash games, horror, educational and the list went on. The casual gamers in their majority played facebook or web-based mini-games.

The idea behind this question was to examine the gaming background of each participant in order to better evaluate their open-ended responses and their gaming session results.

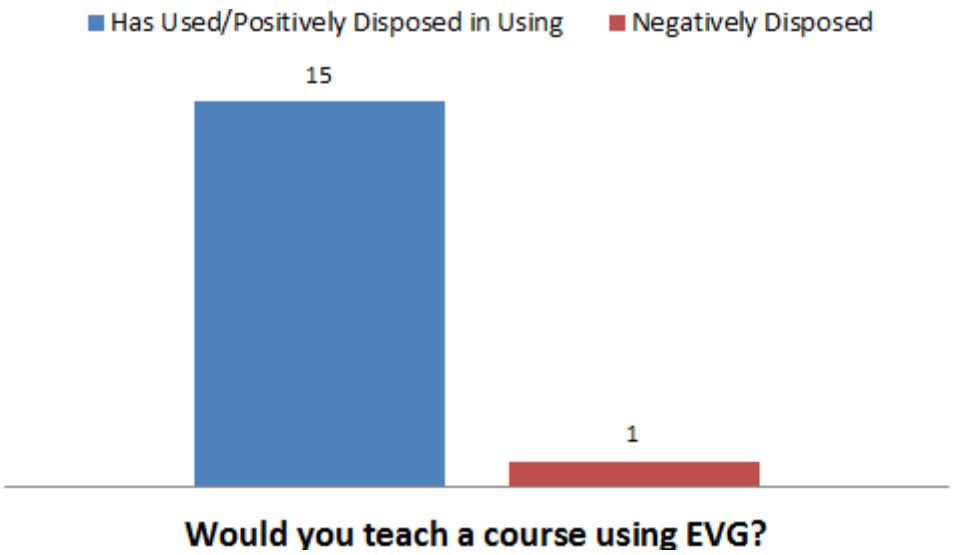


Figure 5.6: Video Games in the Classroom

Use of EVGs in Classroom, Obstacles and Massive Implementation

After reviewing the answers and the results of question 2 and 4 from the Video Games in Education module (see the open-ended questionnaire section in Methodology) i have decided to group the to questions in a single unit because a majority of the participants perceived them in a similar way. The questions are cited: *"Have/Would you used/use Educational Video Games in your Classroom? If not elaborate on your reasons. What obstacles do you think you find/would find? Would you enjoy teaching a course this way?"* and *"What is your position towards the implementation of video games in education?"*. Almost all participants, 93.75%, were positively disposed in teaching a course using an Educational video-game or had already used one in their course and also were positively disposed towards the idea of implementation of video games in education and only 6.25% (i.e. 1 participant) was negatively disposed and declinatory towards using video games in their classroom and in education in general. You can see figure 5.6 for a depiction of the above percentages.

Only three of the participants had already used educational video games in their classroom and the remaining 12 totally embrace the idea. The one participant that was an adversary of the notion of video games in education commented "i would not try it due to time constrains and because i believe that video games role should only be subsidiary". Obviously he thinks that the classical teaching way should be in the center of the attention - this participant was very declinatory to the notion of VGs in education and of course he had every right to, we all have our scepsis' and doubts. But what we owe the constantly growing crowd of students who can't actively participate in a classical, in the above sense, school is to give EVGs a fair chance.

Obstacles

In Greece there is none or almost none implementation of video game teaching in the official curriculum. Some of the participants hadn't even heard of educational video games, this situation is depicted characteristically in a participants comment: "i didn't knew something like Educational Video games existed".

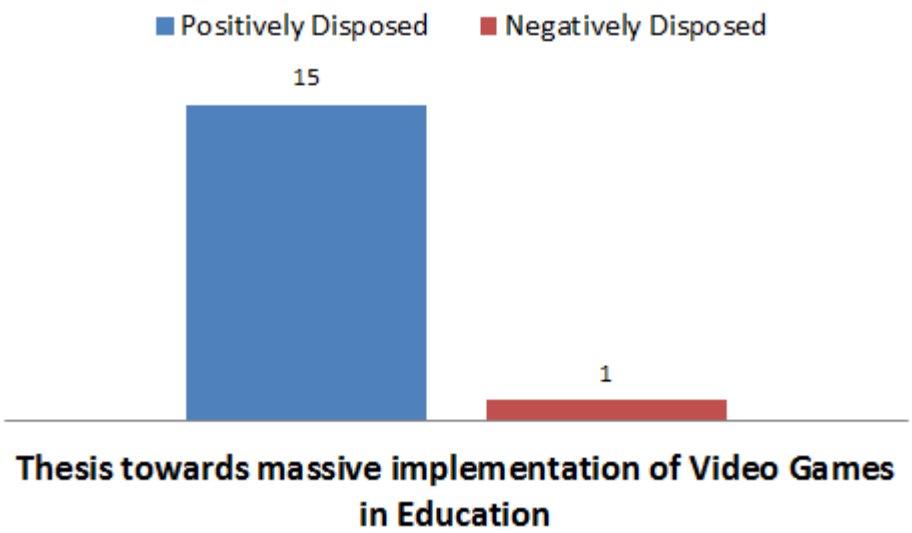


Figure 5.7: Thesis Towards Video Game Implementation

Two more participants acknowledge the Greek Reality of the educational system with their forthright comments: "In Greece as far as I am concerned I know that computer assisted education is not correctly implemented for many reasons...In general I think that education is changing worldwide with the use of technology and Greece should not be the exception." or "In greece we are half a century behind the well developed countries..we should take a stand in video game education if we want to catch up...Massive implementation is far away in Greece at least as I see it".

The participants spoke of many obstacles that they thought would have during a video game implementation in their course. A common issue that arises from many participants, is the time constrain. The Greek education system is structured around a final exams process which, in the case of mathematics, constitutes almost an impenetrable barrier if the teacher wants to try alternative ways of teaching; the course always winds up to go round rote methodology memorization of exercises. A participant states that in our system "educational video games would suit more in a homework environment where the student will play the game at his/her own time". In any case though the teachers should not be bound to the curriculum in a suffocating way but "should be free make their program in order to fit such gaming activities", after all they are trained professionals.

Another issue that is being raised is the student population limits in the classrooms; as a participant reports this, "the student population is vastly greater in classrooms than it should be, this I think will pose a problem in the implementation of video games in education".

In addition another, socially bounded, concern that emerges from the open-ended questionnaires is the beliefs of the social community about video games. Five participants have remarked that the social community around school i.e. the parents of the students should be informed for such an implementation of technology and be accordant; "you can't teach with video games when the parents thinking that you are wasting the pupils' time.." a participant remarks.

One commonly based belief, almost a stereotypical one, is that playing video games is just for fun and thus a waste of time. In Greece, at least as far as it concerns the educational system, this belief has a great number of supporters. Issues like this though, i

hope, can be overcome through better education and information; or else we are wasting a tool with the potential to reform education in lengths that, now, we cannot even imagine. It would just suffice to say that a well known mathematician with prestige in the field who teaches in Stanford, Keith Devlin, plays and recommends for educational purposes a MMORPG game i.e. World of Warcraft[15] and a Winsconsin University professor Constance Steinkuehler has consumed and enjoyed a great amount of time, playing another MMORPG game called Lineage and wrote a number of paper concerning the stuff that you can learn from these practices and how there are not by definition a waste of time (their unwise use though holds a waste of time potential).

Of course i 'm not recommending here to go to the other side and gamify education without rules or special criteria, as two of the participants explicitly state the remarkable ancient Greek quote "everything in moderation" or else the result could be game addicted students, quoting the words of a participant "it may make the students think that all games are beneficial leading to heedless use and game addiction". Some issues have also been raised, by the participants, concerning the health of the students in cases of video-game overuse in school e.g. health issues like eye stress/tension from the computer screen.

Furthermore another issue that is being raised by the participants is the homogeneity between students, here she means the difference in numbers of video game players versus non video game players (in other words the prior gaming experience of the students), could pose a challenge for the teacher who wants to gamify his course. As one of the participants quotes "some students will be overshadowed from better players/students".

The next issue that emerges, by the majority of the participants, is the control of the classroom concern. To put is in the words of the participant "special care is needed in order for the teacher to maintain control and not to result watching his/her classroom transforming into a game room". It is only logical to have a fear like this as a responsible teacher.

Besides the above another obstacle that is being raised concerns the need for proper equipment. This is a serious issue especially for countries, with limited budget, like Greece. An implementation of Video Games in Education requires a personal computer for each student and licensed software, expenses that are substantial and cannot be ignored by the policy makers who will enforce this implementation. Greek schools are under-equipped, concerning their technological materials, and are not ready for such an implementation, at least not without a suitable budget adjustment.

Moreover a concern that has been made by a participant, and as far as i am concerned is crucial to an implementation of video games, was the education of the educators. Educators should be "very well-posted/informed in the subject of educational video games, have a good knowledge the consisting to the game parts and also have pored over through the game manual" as the participant remarks. "It is an ambitious task and in order to pull it through/carry it out we need the best education for educators".

Last but not, in any way, least a student raises the issue of educational video games effectiveness. It must be clear from the research, as she states, that "the video games, which we will implement to our schools, do clearly contribute in students learning" and if i may add that do contribute in a substantial way. She quotes that "if such an implementation is to be made, proper game creation is required" and another participant states that "there should be a careful and informative choice of video games to be implemented".

The idea behind these two questions was to examine the participants involvement with educational technology, i.e. edu video games in their classroom, their thesis towards video

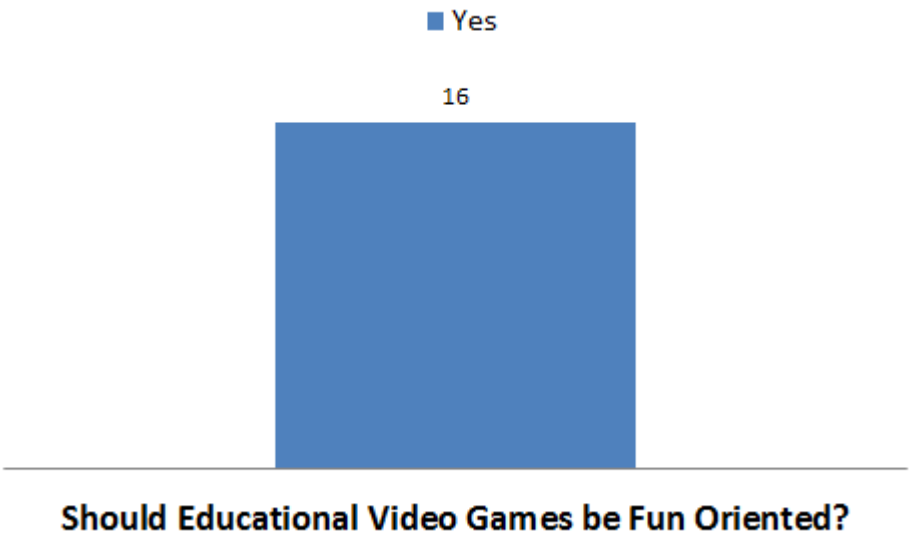


Figure 5.8: To Enjoy or Not the Educational Video Games

gamified education and also see the obstacles that will emerge and have to be fought in order for a massive implementation in education to take place.

Video Games Implementation in Education

The participants are addressing the subject matter in a direct way: one of them remarks that education should be conformed with the current technology and take advantage from its full potential in order not to be outdated and become nugatory bearing always in mind the Greek "everything in moderation" moto. "Video Games could be they key in increasing engagement and motivation of students" she states.

Furthermore it is being stated from a participant that "students will probably participate more actively in a video gamified teaching environment" and that "teaching in alternative ways, such as with video games, once in a while will break the drudgery of the daily routine". Consequently a participant epitomizes the above comments and the need of a reform in education by saying that "video game education can kindle the students' imaginations and provoke/challenge them to learn"

Of course the goal of this procedure is not to replace traditional education, as it has been well said by a participant "video games cannot and will not replace traditional education". As long as humans are humans and not cyborgs or something else there will be the need for human contact and interaction. The proposal that is being made here is to make an educational system that can capitalize the full potential of the students. Besides as one participant puts it "students can only win from the right implementation of video games in education. It is a win-win situation.".

Fun Orientation of VGs

The question that followed was *"Do you think it is good or bad for educational video games to be fun oriented? Elaborate."*. The participants unanimously accepted the fun-oriented aspect of educational video games. You can see figure 5.8 for a depiction of the percentages.

The participants opinions here can, in their plurality, be represented from the participant's following remark: "of course they should be fun oriented isn't it obvious? The more the students like a game the more they will play it!".

Evidently the participants are raising similar concerns about the goals of an educational video game for example i am quoting some of more delicately phrased: "they should be fun oriented but fun must not be the only goal, if not what is the difference between educational video games and commercial video games", "taking for fact that the educational goal of the game is always present I cant see how having fun could be harmful" or "provided knowledge is a goal, fun is always a welcome factor" and "If the games are carefully designed to incorporate educational material i fail to see why can't their goal also be to promote fun?".

One participant accurately summarizes the above comment to the phrase to reject an EVG just because it is fun oriented is like you want to have dismal classrooms, "why cant we have fun while learning?" she states. A comment that reminds us the opposite of the prefaces' fun in learning stereotypical belief of Benjamin Franklin "Things that hurt, instruct". I bet that this comment does not sound so logical if you have made it this far.

The potential of this technology, as i see it, is infinite. The participants advocate this with their comments: "a video game can subliminally achieve what classic education can't do when you are conscious. The educational goal could be a byproduct of this fun-oriented procedure aka(=also known as) gaming" and "the target: to make the students learn without understanding the procedure..". These comments remind us of the flow state described by Csikszentmihalyi in the preface.

I am closing with the words of a participant which are in the spirit of the ancient Greeks' everything in moderation moto "we should find the golden section between having enjoyment-centered educational video games and abundant didactical payoffs".

The concept behind this question was to examine the beliefs of the participants concerning educational games and around the "knowledge only through pain" moto in order to better evaluate their stances and their beliefs.

Suitability of Courses for EVG Implementation

The fifth question of the Games in Education module was *"Do you think that any of the subjects taught in schools is more appropriate to be taught through video games?"*. The participants answers were somewhat divided. The majority of the participants, 68.75% believed that any course under the right conditions can be gamified, 12.5% supported that Theoretical Courses like history are more suitable, 12,5% voted for Natural Sciences Courses like Physics and 6.25% (i.e. 1 participant) completely disagreed with the notion of VGs in Education. You can see figure 5.9 for a depiction of the percentages.

The majority of the participants can be more accurately represented by comments like the following: "Any course can be videogamified, for some courses it will be easier than others, but under the right terms and conditions VGs implementation can be a reality". The two participants that supported the theoretical courses position did so because they thought it is more necessary at todays school to save the students from the drudgery of rote learning.

The idea behind this question was to learn more about the participants beliefs in order to make an informative evaluation of them but also to examine the prevalent trends-beliefs in the subject matter in the Greek reality.

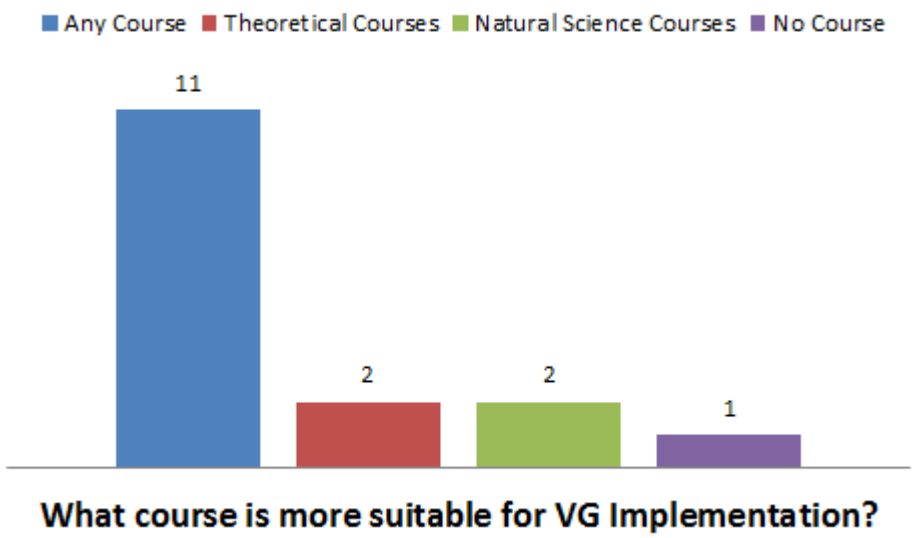


Figure 5.9: Does VGs Implementation Suits Best to a Specific Course?

Genre Differences

The sixth and last question of the module was *"Do you believe that there is a difference between male and female video game players? Elaborate."*. The participants, with 93.75% percentage, reach their verdict which advocates in favor of the no genre difference position, and only one participant, 6.25%, embraces the possibility of genre differences . You can see figure 5.10 for a depiction of the percentages.

The stereotypical viewpoint is that boys are better than girls in VGs, but as participants quote "any difference there might be has only to do with the time somebody plays the game and not on innate gender issues", "i don't believe there is any cross-gender difference in the innate VG skills of a person" and "if there is any difference is not due to actual skills but due to acquired skills". The one participant who replied with a "maybe" in the genre differences question did so in an academic basis, as she quotes "maybe...probably not thought, but it should be researched".

Congruently to the above questions the main idea here is to get more information about the participants and their belief for better understanding of their answers.

Satisfaction by playing NNG

The next module in the open-ended questionnaire concerned the NNG, as it has been mentioned in the OEQ section on the Methodology chapter, and the first question was *"Did you enjoy playing the NN game? Why or why not?"*. The majority of the participants, 87.5%, enjoyed playing NNG (at least for a while), 12.5% (2 participants) did not. You can see figure 5.11 for a depiction of the above percentages.

The participants enjoyed, in general, playing the game. You could see it at their faces even one of the 2 participants that replied that he did not enjoyed the game played it for almost 4 hours straight. A possible reason could be that almost none of the participants except 3 had ever had experience with VGs but let us hear them through their responses.

In this paragraph i am giving some of best phrased positive reviews to the game: "it was addictive", "I lost track of the time and did not understand how 2 hours passed so quickly", "i liked it from it's graphics/design to it's goals", "it is interesting and creative",

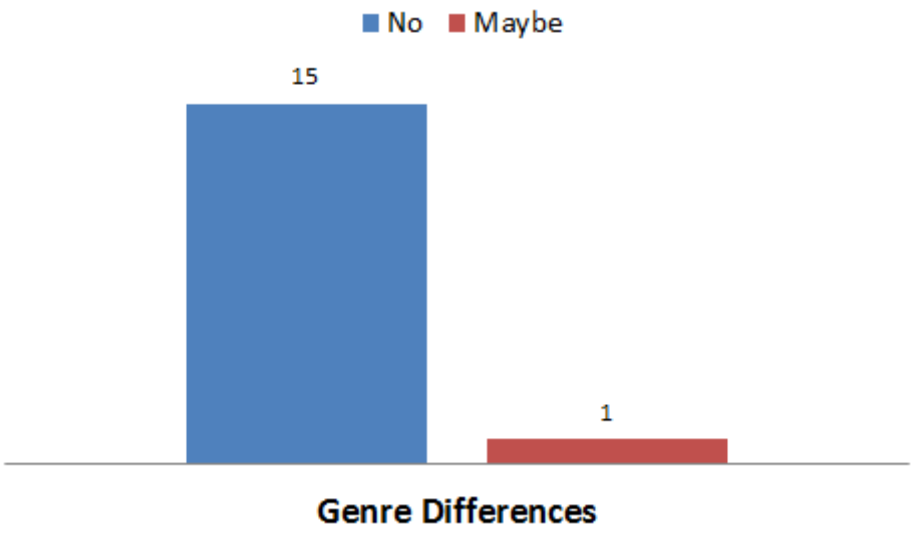


Figure 5.10: Beliefs About Genre Differences

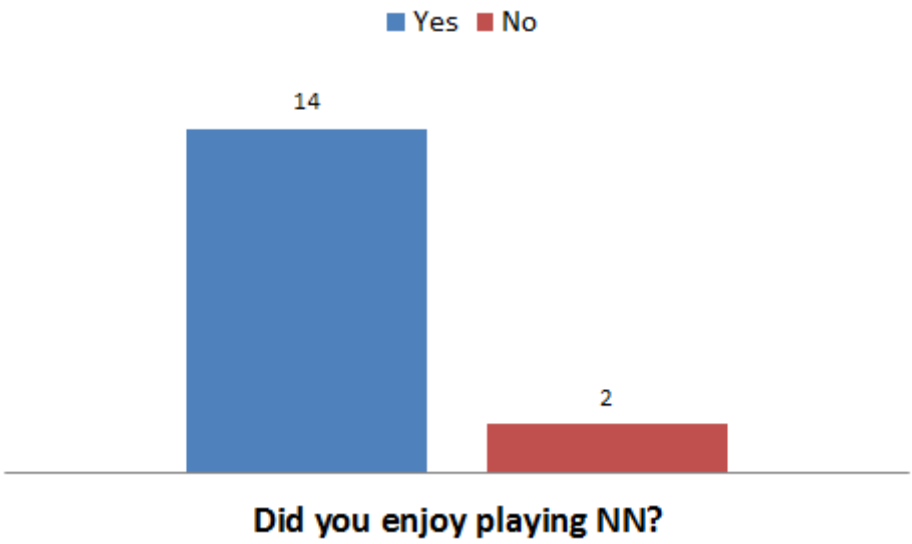


Figure 5.11: Thesis Toward NNG

"it gets your wheels in motion in order to find the optimal solution (here she refers to the energy mode of the game)", "it would be an innovative way to teach mathematics calculations" and "it is peaceful in comparison with other VGs (this comment has been made by a casual gamer participant who shared the stereotypical belief that games were all about blood and gore)". Two of the participants praised specifically some features of the game saying "i did enjoyed the game especially the energy levels which where more demanding. The moves levels were trivial" and "it was enjoyable, the gold medals were a great motivation".

Some of the participants, thought they replied that they enjoyed the game, wanted more from it. Their replies speak for themselves: "yes i enjoyed it but it could be more attractive" and a comment that expresses many of them "yes i enjoyed it for a brief period, after that it became monotonous".

Some interesting opinions expressed by the participants about the game were that the game "promotes strategic reasoning and data cross-examination skills which are needed in todays world", "it requires high mental awareness, memory and strategic reasoning" and that it is "a brain training game in calculations". One of the participants parallels NN with crosswords puzzle solving and he means this in a brain teasing way. Last but not least there was a participant who commented on the brain teasing way that the game is designed that "I fancy those mind boggling activities (speaking foremost for the energy mode)" which can be matched with the pleasantly frustrated condition that Gee talks about in his book.

The idea behind this question was to examine the preferences of the participants gamewise and to hear possible critiques concerning the NNG.

Mathematical Skills in NNG

The next question in the module concerned the skills that the players used while playing NNG and the question was *"Did you employ any mathematical skills, concepts or processes while playing the game? What were those?"*.

The classical mathematical skills that the majority of participants reported they used were:

- calculations of mathematical operations
- factoring (analysis in primes)
- least common multiple
- greatest common divisor
- divisibility rules
- distributive property
- properties of mathematical operations and of natural numbers
- prime numbers
- breaking numbers in smaller "bits"
- number theory properties

Two non innately mathematical skills that some participants referred to were "to device a strategic plan to move the ship" in order to escape from the pirate and avoid terrain obstacles and to "pick mathematical operations strategically in order to make your route optimal (here he means scorewise in energy mode and movewise in moves mode)". Playing NNG the participants need to use various number operations combinations in each of their move these combinations need to be strategically selected, taking into consideration constrains from what numbers are covered by land to scoring modes of the game (energy/moves). In accordance with the previous participant another one remarks that "these open ended problems e.g. go from 25 to 55 make you think how you can use the operations in the most efficient way". The next participants' answer is to the point discovering without any help an integral part of mathematics video game education, that is as he says "the mathematical procedures were integrated in the game elements/features".

Reflecting in this question i would like to emphasize some of the skills that i believe somebody can get from NN. First of all the player in NNG is dealing with a vast variety of calculations and this i think can affect his understanding of the relationships between numbers and operations in a more conceptual way. Furthermore, as formalization in mathematical writing is consider essential in order to understand higher mathematics, i believe that NN holds some potential here as it facilitates visualization of math operations and links it with symbolic representation. When you are adding or multiplying in NN you are able to observe the trace of the ship and thus visualizing the arithmetic operation and connect this visualization with its symbolic representation. Of course there is a problem with division which does not match its in-game representation i.e. division is represented by a straight line. This only refers to the conceptual representation of the actual division.

In this question, the main idea was to check the mathematical skills that the participants used and to understand their strategy and way of reasoning in the game. Having decided that the gaming session logs would not be analyzed this question was a great help in understanding the above and better evaluating the participants responses.

Negative Emotions During Gameplay

The third question of the NNG module was *"While playing the game did you observed any anxiety, tiredness or need for confirmation of any kind?"*. The participants responses categorization arose from the analysis of their open-ended responses. First there were those who did not experience negative feelings at all during the gaming session, 31.25%, next and foremost where the participants that experienced fatigue and boredom during game play, 37.5%, followed by those who experienced stress during playing the game, 31.25 and lastly those who needed confirmation while playing, . You can see figure 5.12 for a depiction of the above percentages.

The participants who experienced fatigue during gameplay communicate their feelings in their responses. A common response that depicted the majority of the participants was "i was bored after a while, the game was monotonous". Two of the participants mention that they experienced some fatigue but they attributed this to the fact that they were playing the game for 2h straight.

The participants that experienced anxiety during gameplay express their emotions in their open-ended responses: "i 've experienced stress in the form of pressure in order to get the gold medal", "i was anxious because i did not know what i would face in the game, for maybe i couldn't comply" and "i was a little stressed by the competition because i wanted to be ahead of everybody else (some of the participants that have been paired,

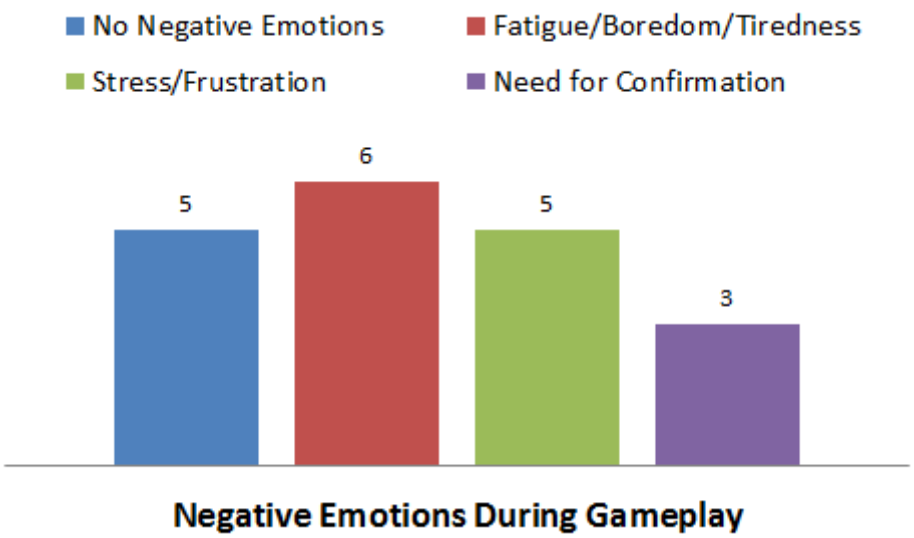


Figure 5.12: Negative Emotions During Gameplay

challenged each other but this decided not to consist a research design feature as it has been remarked in the NNG chapter)". One participant commented as a negative feeling sadness specifically she says "i experienced sadness for not being able to undo unnecessary mistakes". I have categorized her answer under the stress/frustration category of negative feelings.

Last but not least i am presenting the comment of the pilot participant "I was stressed because I was given a specific task, i.e. i had to accomplish as many levels as I could during the 2h gaming session". After reflection on this comment and on his total open-ended questionnaire i decided that i'd better let the participants play freely the game, after all participating in this project should be a fun experience for them. If i pushed them i would feel like Doctor Mengele, the infamous SS concentration camp physician.

The participants that experienced need for confirmation while playing the game explain their emotions saying that "I felt need for confirmation at the first stages of the game until I firmly grasped the game concepts" and two other participants report a vague need for confirmation in some parts of the game.

The participants who did not experience negative emotions comment that "I wanted to go beyond the defined time" and "I wanted to go on".

The main concept behind this question was to observe the gaming experience of the participants in order to better understand them and to examine how did they felt by playing NNG. Reflecting on the question, having seen the answers of the participants i am concluding that the question should be phrased this way: "While playing the game did you experience anxiety, fatigue, need for confirmation, or other negative emotions?". I am suggesting this because i think that the first expression was narrowing down the choices of the participants to the three choices that were already provided not leaving the any space to think and track down any other negative emotions that may have been caused by the game.

Motivation To Play The Game Afterwards

The fourth question of the NNG module was *"Did you found the game motivating? Would you have played it in your own time?"*. The participants responses were categorized with

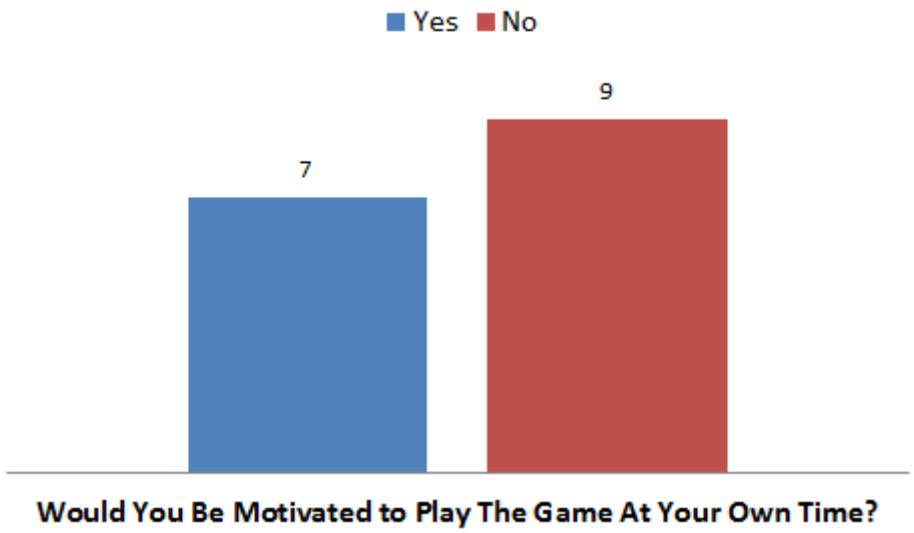


Figure 5.13: Would you be motivated to play the game in your own time?

a yes or no taxonomy. The participants were divide in this question. The percentage of those that declared they would play the game in their own time was 43.75% in contrast to 56.25% that would not play the game in their own. You can see figure 5.13 for a depiction of the above percentages.

The participants that would play the game commented that "i would just play it out of curiosity for being classified as a mathematics EVG", "i would only play the energy levels", "only to make every medal a gold medal", "only to improve my fluency in calculations not for the fun of it", "i like playing games with numbers", "the game internally motivates you for brain training calculations" and a last one "I would play it like a game you play in order to get better scorewise for example Tetris".

The participants that replied declinatory in the above question remarked: "no way for more than 2 hours", "in general i would not play the game only in the case that I wanted to teach it in my classroom (she liked the way of thinking that the game promoted though)" and the last commentator says "i wouldn't play it because it is becoming addictive after a while and you can lose valuable time".

The main concept behind this question was to observe the stances of the participants towards NNG and along with their gaming session behavior better understand and evaluate their responses. Reflecting on the question, having seen the answers of the participants i deduce that the question should not consist of two parts and be something like this: "Would you be motivated to play the game in your own time?". I am suggesting this just to have a better phrased question and to avoid misunderstanding problems which did occurred from this question.

Motivation from Game Goals

The fifth question of the NNG module was *"Did you think that the in game - necessity to build a city, through the collection of materials, would be motivating enough (presents an appropriate level of challenge) for students?"*. The participants responses were categorized with a yes or no taxonomy. The majority of the participants, 62.5% believed that the game goals would not be motivating enough for a student to play the game against 37.5%

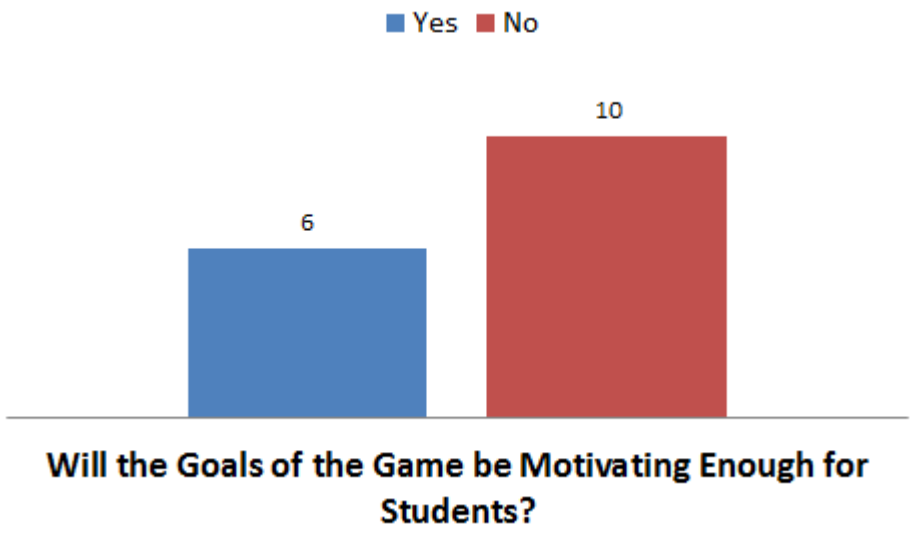


Figure 5.14: Will the In-Game Goals Be Motivating Enough For Students?

that believe that the goals were sufficient enough. You can see figure 5.14 for a depiction of the above percentages.

The game's main goal, as it has been extensively discussed in the NNG Chapter, is to build a city by collecting 4 materials; and as a byproduct of this goal, a by-goal if you will, you are getting medals (bronze, silver, gold) according to your performance. These were the virtual properties in NN. The acquisition of these assets provides players with a major incentive to play and take on new challenges as Devlin remarks[15].

The majority of the participants failed to see the main goal even some of the participants that though the game was motivating enough did so because of the gold-medal acquisition by-goal. "The only target I can see is the gold!" one says or "you don't see the building of the city anywhere else except on some screenshots for some seconds, medals were my motivation", "it was not a clear goal..the only goal as I saw it was to achieve a high score (here she means medals)", "build cities? no, i did not even perceive it this way", "I don't think that it was a substantial goal, after all the city building just consists of 4 different pictures which are the same in each level and are being shown in a pop-up window (which interrupts the game flow, if i may add) for seconds until you press the continue button" and "I forgot about building the city after the starting levels it was clear that I was only making calculations to get more medals" were some of the participants well articulated remarks.

One participant acknowledging the problems of the in-game goal goes far enough to suggest a solution "I don't find it right as a goal..maybe there should be an interconnection between levels in order to build something bigger like an Empire..a more general target".

A temperate comment that could summarize the above is that "for the majority of the students the answer in the question, are the in-game goals motivating enough, I think would be no".

There were participants though for whom NNG did the trick: "I would characterized it as sufficient (the goal)" or "could be sufficient for elementary grades students", "it is a common concept in strategy games like Settlers of Catan, my favorite board games", "it is familiar (the concept) for gamers e.g. Age of Empires, Civilization, Anno, Starcraft etc" and last "I think that the city creation is motivation in itself".

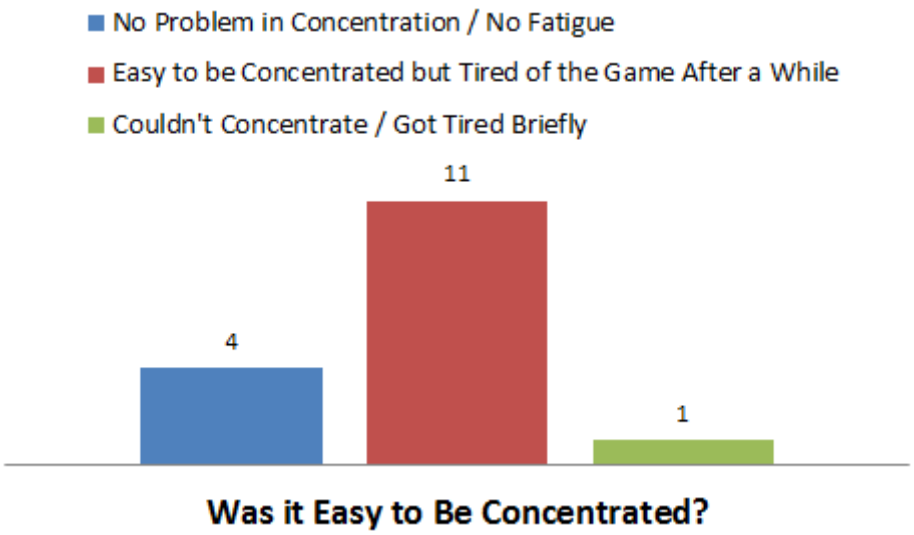


Figure 5.15: Easiness of Concentration During Gaming Sessions

The idea behind this question was to find out whether the game goal was intriguing enough for the participants, as it turns out this is not the case.

Easiness of Concentration and Fatigue

The sixth question of the NNG module was two-folded, the first part was *"Was it easy to be concentrated in the game?"* and the second part was *"After how long did the game tire you, if it did?"*. In the first question a three answer rubric was followed for the taxonomy. There were the participants, 25%, with no concentration problems and who did not got tired from the game, those that easily got concentrated but grew tired briefly, 68.75% and those that couldn't concentrate at all and got tired after understanding the main features, 6.25% (1 participant).

In the second question the answers have been categorized following a four answers rubric. First there where the participants that reported no fatigue, 25%, followed by those who got tired after 30-45 minutes, 18.75%, those that got tired after 60 minutes of gameplay, 6.25% and those that got tired after 90 minutes of gameplay, 50%. I want to remind here that the gaming session was 120 minutes (i.e. 2 hours) and that the participants were offered a break of 10-15 minutes (which not all of them made use of). You can see figure 5.15, 5.16 for a depiction of the above percentages.

The participants quoted about the game that "it demanded a deep/high level of concentration especially in the energy levels", "after a will the second stage i got absorbed by the game" and "I wanted to go on even though I was bored from the game concept in the starting levels". One of them points out the importance of engagement while playing saying that "it was easy at start..but I got tired quickly and then it was difficult to be concentrated".

Reflecting on the research design i can confirm what i was afraid of, when designing the research's framework, i.e. the gaming session should be divided into 2 parts. A single gaming session was barbaric! To quote a participant "I was concentrated during the whole session, I think though that 2 hours straight game playing was barbaric, in general though I was not tired but I couldn't play another energy level..it was mind-boggling".

The participants' answers in the open-ended questionnaires depict accurately this sit-

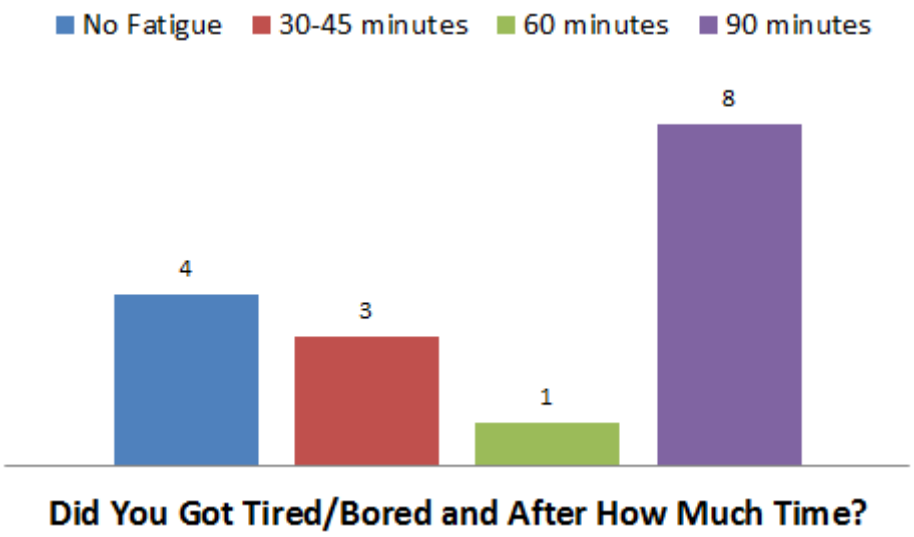


Figure 5.16: After how long did the game tire you, if it did?

uation. The majority of the participants were off after 90 minutes time, "after 90 minutes I got tired and I was making silly mistakes like confusing plus sign with minus sign resulting in lower scores than I could achieve not being tired" or "after 90 minutes I got tired of doing calculations, i am not saying that i did not like the game though" and "i think that 2h straight is the maximum".

The concept behind this question was to learn more about the in-game experience of the participants and figure out the time limits of the gaming session.

NNG and Grasping Students Attention

The seventh question of the NNG module was *"Do you think that this game can catch a student's attention/interest?"*. In this question a three answer rubric was followed for taxonomy. There were the participants that believed that NNG could attract the students unconditionally, 18.75%, those that supported that the game can attract the students for a short period of time, 75% and finally those that believed otherwise, 6.25% (1 participant). You can see figure 5.17 for a depiction of the above percentages.

The majority of the participants stated that according to their experience in the education field and to their personal opinion the students would play the game but will get tired of it easily. The participants comment that "after understanding the reasoning of the game they will get bored", and that it will better be implemented in "elementary grade students", for a few times and auxiliary to the classical teaching methods mirror this concern. "Maybe only competition could make the game interesting enough for a massive implementation and this would not apply for everybody" as another participant quotes. Most participants advocate for application in elementary grades but in greater grades of education "the implementation will be tough because it would be difficult enough to motivate the students".

Almost all participants agreed either by articulating it clearly or by criticizing some of the game features that "there are a lot of changes that should be made in order for the game to become attractive enough for the students" and for a massive implementation if i may add.

Instead of traditional teaching "students would surely prefer NN" one participant

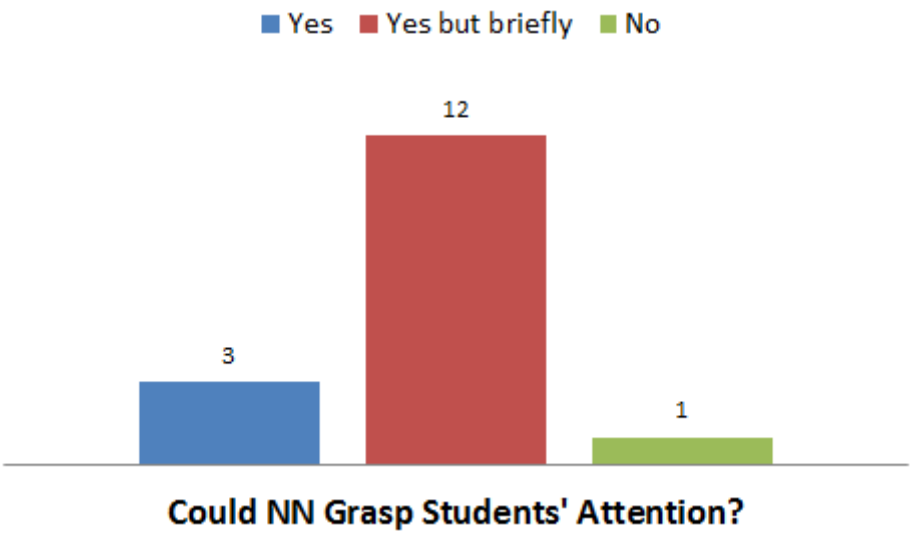


Figure 5.17: Attractiveness of NNG

remarks. Another issue that is being raised from participants is "I don't know if such a game can grasp the interest of students that don't like math." and the participant for sure has a valid argument here. Unless there is a gamified version of the game that is guaranteed to attract students attention, classroom implementation cannot be advised. It would not be fair to leave students behind.

Moreover a comment that has been made by three participants was referring to the comparison of NNG to commercial video games. "Todays students are used in more attractive VG designwise and goalwise" and that the game "is nothing like commercial games". I am concluding with a participant who advices that NNG "should bridge the gap to commercial video games the creators should work on the engaging part" before classroom implementation can be advised.

This question was included in the questionnaire in an attempt to grasp the participants beliefs and to beta test[61] NNG based on the participants strong didactical background and educational experience.

Use of NNG

The eighth question of the NNG module was *"Would you use this game as a supplemental tool/material in your classroom and/or as take-home practice for your students?"*. In this question a four answer rubric was followed for the categorization of the participants responses. The majority of the participants, 75%, replied to the question that the would both use NNG as supplemental, to their course, material and also as homework material, 6.25% replied that they would use NNG only as supplemental material, 6.25% would only use NNG as Homework material and 12.5% most probably wouldn't NNG at all. You can see figure 5.18 for a depiction of the above percentages.

Some of the participants were very excited by the mere existence of such educational game: "Yes to both, especially in the elementary grades of education, i will also give it to some of the students that I m currently instructing".

Another participant remarks that he would "only use it in the absence of better games. It would definitely not be my first choice...maybe like homework material but only having strictly defined the parameters e.g. exact time that the students will play and then

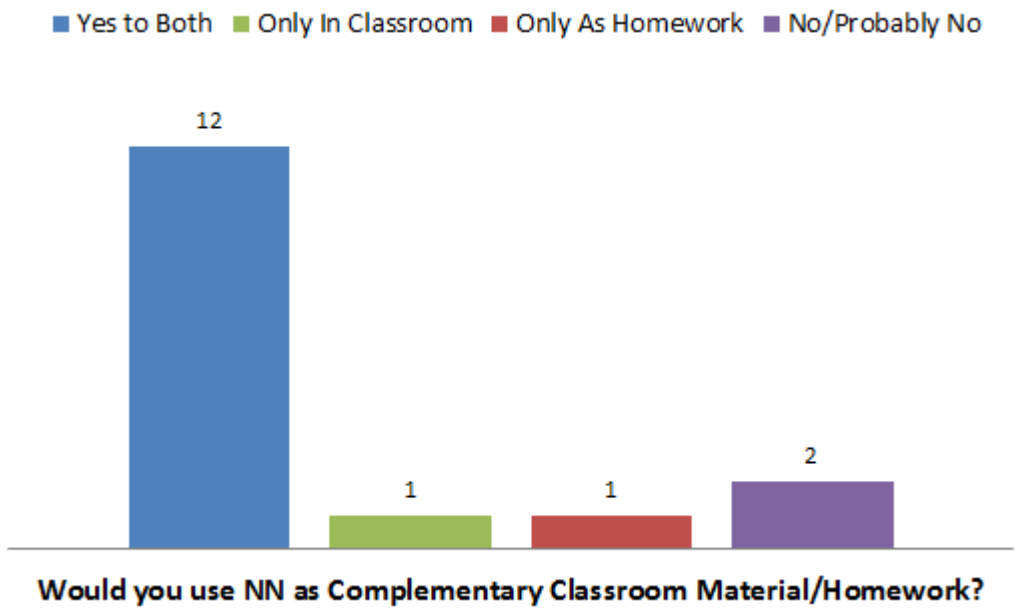


Figure 5.18: How would you Use NNG

try to examine the gains from the game if there were any". Finally One of classroom use proponents emphasizes that he would use NNG "only in classroom where I could implement the competition element in the procedure".

This question had been placed in the questionnaire in the beta-testing reasoning that was mentioned above and in order to examine the participants opinions in the subject matter.

Difficulty of NNG

The ninth question of the NNG module was *"How you would characterize the game's difficulty? Explain."*. In this question the responses of the participants were divided into 3 main categories, the classical ones when somebody speak of VGs. The majority of the participants, 56.25%, found the game to be of normal difficulty, 37.5% found the game to be rather easy and 6.25% (1 participant) thought that the game was hard. You can see figure 5.19 for a depiction of the above percentages.

The participants unanimously reported the triviality of the moves-mode stages and almost all spend a lot of time trying to handle the game in the energy mode. As they quote "it is easy enough for a student on moves mode but in energy mode it would require more skill in order to find an optimal route" and "I think that in some energy levels the students may not be able to comply at least with their first try".

One participant makes a very strong argument, as i can evaluate it, having played NN more that 15 hours: The game's difficulty is "easy but there was difficulty in game control..for example you had to click with the mouse the symbols button of the operations in the game. There should be an easier way", a more integral way if i may add, "to input numbers and operations or at least everything should be done with keyboard's numpad". The proposition that the participant makes is crucial and i am totally backing it up, i think that it could pose a great improvement to the game.

This question was included in order to evaluate the participants view of the game's difficulty in the beta-testing logic that was suggested above.

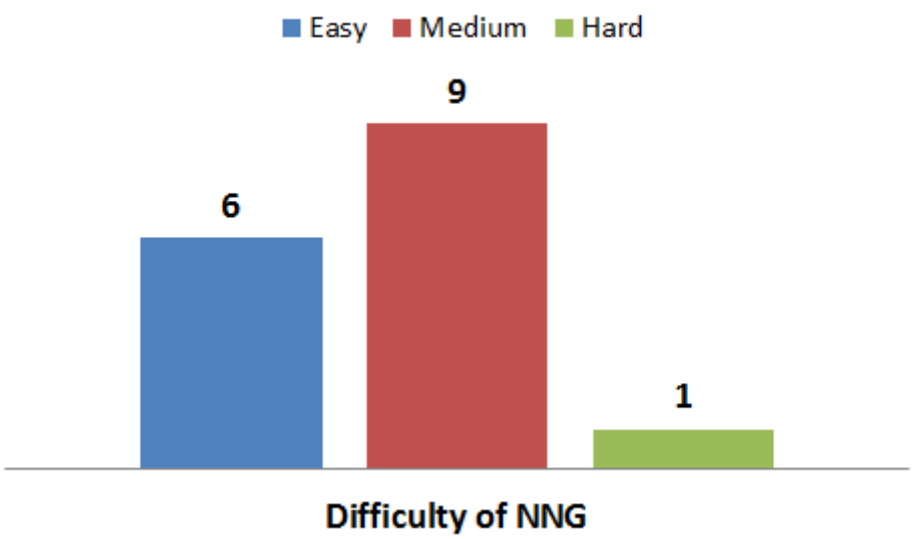


Figure 5.19: Difficulty of the Number Navigation Game

Engaging/Fun Features Of NNG

The tenth question of the NNG module was *"In your opinion what aspects of the game were the most engaging/fun?"*. All of the participants liked something particular in the game. The categorization that has been made is not a strict one and aims to statistically present the most common answers of the participants. The categories are not clear and i certain choices cover each other. For this reason i don't think that it has much value to present exact statistical percentages just a mere depiction of the categories in a graph would suffice. You can see the graph in figure 5.20.

The majority of the participants reported that the most engaging feature of the game was the energy mode as they put it "energy conservation feature in the energy mode", one participant goes even further and parallels this energy conservation mode with the congruent problem in our "energy driven societies". "The energy mode was puzzling at start, it was a brain teaser" that kept him pleasantly frustrated [20], if i may add.

The second most popular feature was the medal system, the participants were very excited to get gold medals, thus improving their overall score. As they comment "i wanted to fill the screen (the starting screen he means here) with gold medals"

Some of the other features that the participants really connected to were:

- the terrain restrictions
- the use of mathematical operations
- the graphics of the game
- the ship graphics
- the challenge to do my very best scorewise
- the variety of possible routes and that you 've got to find the optimal one
- the collection of the building materials
- going back to the port/reverse calculation procedure

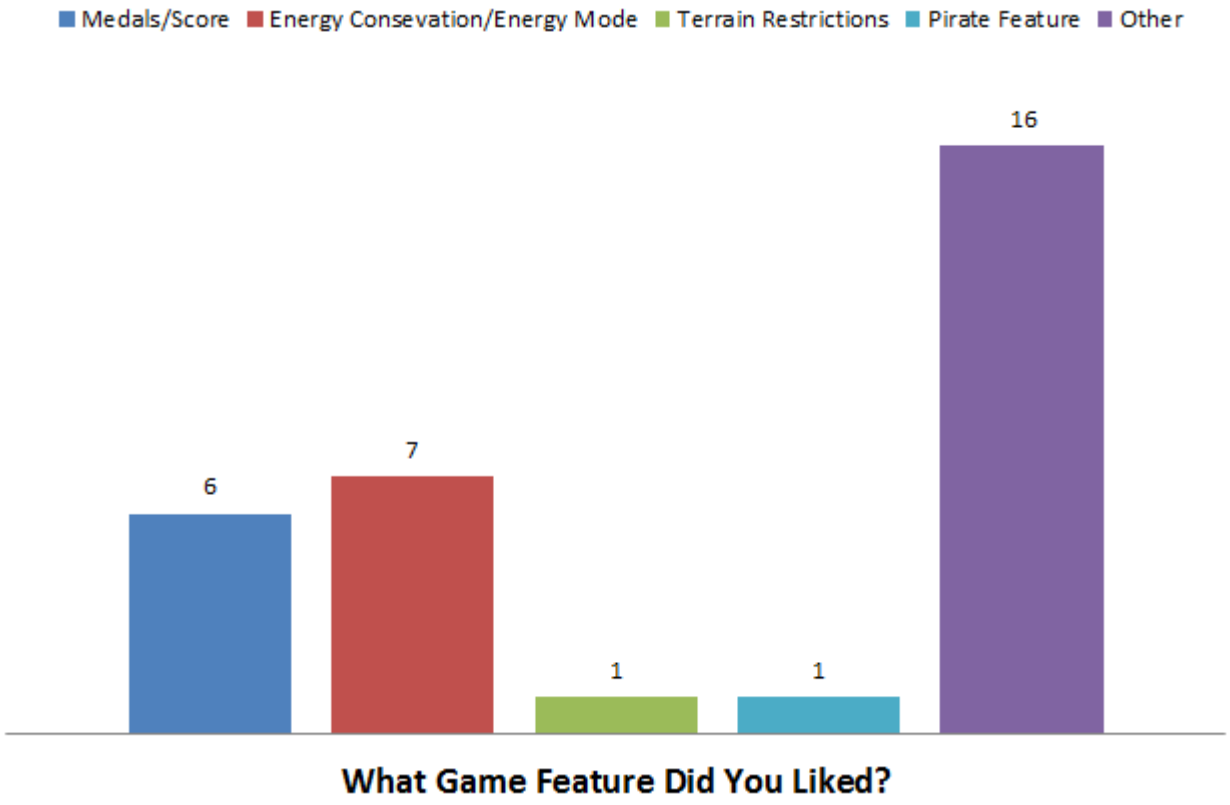


Figure 5.20: Engaging/Fun Features Of NNG

- the pirate feature

  A nice participant's comment concerning this feature was: "I really liked the pirate feature..you think you 've got the gold medal in your pocket and boom the pirate appears..it's surprising!"

- getting better at calculations

- that it was about mathematics

  As it has been quoted: "I liked the game's (integrated) mathematical design where you make your brain solve the equivalent mathematical problem without realizing it".

The question's aim was firstly in accordance with the beta-testing logic that has been described above and secondly to contribute to the participants "profile" in order to examine their preferences and what they fancied in the game.

Propositions For Modifying NNG

The eleventh question of the NNG module was *"Are there any expansions/modifications to the game that you would recommend?"*.

In this question the participants overwhelmed me with their ideas, some of them are pretty "linear" but the majority of the participants had something good to add. I am attributing this quality of propositions to the quality of this study's sample.

The most common proposition of the participants was the existence of an undo button. As they say "an undo button would do the trick..if you made a mistake and wanted the

gold medal you had to restart the level to make things right" and "the game needs an undo option at least for the last move".

I am not advocating for an undo button though, because i believe that mistakes are part of the learning procedure. For example some mistakes in a level and a bronze medal, the worst one you can take, may make the participant try harder and thus signal his improvement.

The graphics were very poor, at least from a gamer's point of view. There were three participants that advocated better graphics either partly by saying that "the graphics of the city in each stage could change" or as a whole "the game needs better graphics and design if it is to compete with commercial video games in a way".

Graphics is not an easy matter when designing and creating a video game because it most certainly translates to more money thus needs bigger budget and getting the necessary know-how. In this initial stage that the game is now, i believe that the best path to follow is firstly to calibrate the main features and when there is a stable and successful (resultwise) version of the game to invest money for graphics improvement.

The next suggestion that has been made concerns the Pirate feature which "becomes easily predictable after a while..it should be randomly generated in a specific area". I am totally backing up this participant and advocating such a change. According to Malone, as it has been mentioned in the theoretical framework of the study, randomness in games plays a very crucial role and is an essential attribute of good games.

Moreover to the modification of the pirate another participants support that "the existence of more obstacles that try to get into the route of the player in order to make him think different calculations". Although the participant does not name such obstacles it is not very difficult to think of something e.g. there could be a water-dragon like "Nessy" from the Scottish Highlands or a tempest in the sea (some specific squares of the 100-grid that would be inaccessible).

I am advocating features like the above for two reasons stemming from Malone's framework about good games, firstly because they would add to the game's complexity and secondly because they would add to the variety of the game's features. Complexity and variety (as a participant remarks "more variety in stages is needed") are both features that the game lacks of.

An additional proposal for modification of NNG appertains the scoring mode of the game, in particular a negative scoring in the way of moves/energy penalties is proposed by a participant. This feature, i believe, has some potential in the a behavioristic punishment kind of way which would not be too overwhelming to make the player abandon the game. I thus stand for such a modification.

Furthermore one participant suggested a "time mode with easier levels so the players would be pressured to make calculations faster". Such a mode is common in today's EVGs, like for example in DimensionM, the subject matter here is the direction that the creators of the game want to give and the goals the they want to achieve through playing the game.

It is sure a valuable skill to make calculations quickly but it would downgrade the game to rote drill and practice which should not be the terminus of Mathematical EVGs. I am not negatively disposed in the creation of such a mode though, far from it, it could be part of the game, i just want to highlight possible dangers.

To go a step further another participant proposes that "a ranking order in the stages from easier ones to more difficult ones" because she was "swamped" as she remarks by not knowing where to go next. Freedom of choices is something that everybody wants but

when achieved, there are problems managing it, of course this is not the rule in general but it applies for some people.

The participants comment, as i had grasped it, follows the above reasoning. I would not say that i oppose to the proposition of the participant, at least not if we are speaking for a relative order of the stages in each level. For example there are X easy stages, Y normal stages and Z hard stages, but i would not stand for an absolute order e.g. you go from stage 1 to stage 2 to stage 3 and so on and so forth because of the linearity.

Besides the above time mode proposition, a participant goes even further and proposes a specific idea for a time mode that he came up with, as he says "a time mode where with each move an new obstacle is being added (in the 100-grid)". It's an interesting idea in the above logic and thus i believe it should be considered.

Complementary to the above another participant advises for "more autonomy to the player" as she says, and to achieve this he stands for more complexity and remarks that "maybe more materials (are needed) from which the player would be able to choose" as an addition to variety. As i have made it clear before i am pro adding more complexity and variety features to the game. Today's students can handle more information, or to say it better more in-context information, that we accredit them to, let me only say for example that Squire implemented a modified version of Civilization, a 250-pages-manual game, with relative success.

An also valuable suggestion, at least from my point of view, that is being made by a participant is to add music to the game. Of course i know that the initial design of the game was done this way in order to have minimal requirements[19], as it has been clarified in the NNG chapter, but it should at least be consider as a possible version of the game.

Indeed, the positive effects of music in concentration are indisputable, i only am citing two articles that i have in mind concerning the subject matter. Of course the bibliography on the positive effects of music is massive and greatly exceeds the aims of this study. The Shih paper [62] concludes that there is a positive correlation between work concentration level and background music while study from the Stanford Medicine news center [8] finds that music moves brain to pay attention. And if anything the game needs **any** boost in engagement that it can get.

There are many participants that advocate for modifications in the game but vaguely because the concepts that they propose to be modified require a lot of though in order to come up with a right idea. I am giving their suggestions as they are: "A greater motivation for the students is needed", "I think the game could be something better the current target is not intriguing enough.", "it's a good idea but it needs improvement if massive implementation is the target", "more game features should be implemented" and "There should be a modification in order to make the game attractive to students who don't like math". If you observe closely every comment targets in a direct or not way the subject matter of engagement.

Last but not, in any way, least a participant proposes an extension of the game to algebra. This integration of algebra to educational video games is in the cutting edge of the field of video games in mathematics education. The main problem is to implement the algebra in a non-drill & practice way and to break the symbol barrier i.e. not to represent mathematics with the formal mathematical symbolization, as Devlin has define it in [15]. A way to implement symbolic algebra in a video game this way could be to change its representation. Maybe you can do something like this through geometry but of course i am in no way ready, from my master thesis stand, to propose something concrete here, i can only direct you to a VG with a very innovative way to implement

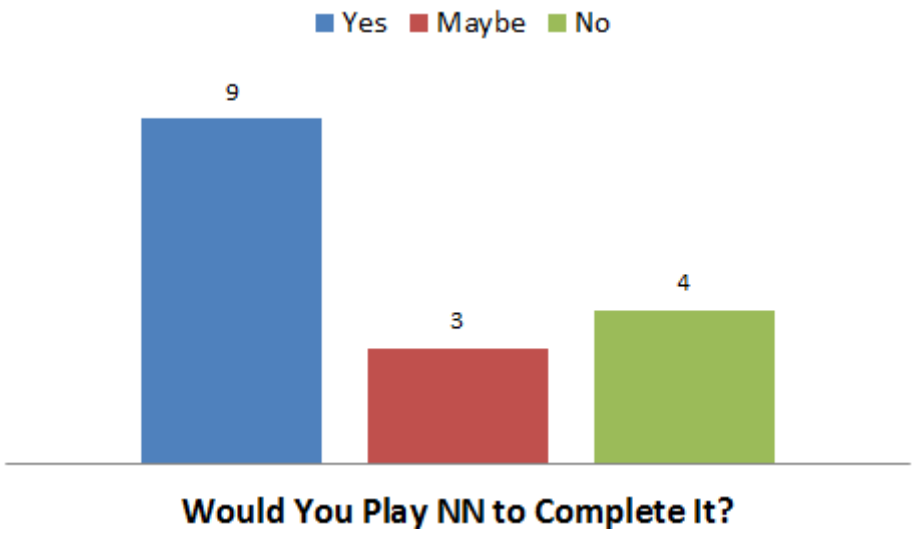


Figure 5.21: Would you play NN in order to complete it?

mathematical operations, having played and completed it. The game is Wuzzit developed by BrainQuake Inc. and Devlin participates as the "BrainQuake's Math Guy" and for a brief presentation you can see the Appendix C.

To remark another participant's comment concerning NN which is in the above spirit "the math should be more integrated in the game in order for the game to be fun and to make the students play it more" and if i may add to support the flow-state potential of the game.

This question logic followed the beta-testing spirit that has been mentioned above. I wanted to have the participants give me feedback about the game in order to make an informative critique of it but also to help the Finnish team in designing a better and more stand-alone, if you will EVG.

Completion of NNG

The twelfth and last question of the NNG module was *"Would you play NN aiming to finish it?"*. In this questions the responses of the participants were categorized into 3 main categories. Firstly were those that would complete the game, 56.25%, followed by those that would not play the game, 25% and finally those that posed some constrains or just weren't sure 18.75%. You can see figure 5.21 for a depiction of the above percentages.

The percentages here are self-explanatory and the answers of the participants were short and to the point. I will only quote three short excerpts, one from each category: "the only way I could play it would be in a competition mode but as such a mode does not exist i am obliged to say no", "maybe, if I wanted to get better in calculations or had a lot of free time" and "of course, it was hard enough to stop".

Four of the participants got so addicted with the gold medals and the energy mode that in a week time, completed the whole game and sent me a copy of their gaming logs. It is very interesting and intriguing, for me at least, to observe the power the game had to some participants, it was almost like somebody has casted a spell on them. This power shows, as i perceive it at least, the true potential of the VGs in education, if something like this can happen to well-educated adults image what can happen to students. Maybe we are a ludo-animal in the Vygotskian point of view or to put it more eloquently a

homo-ludens as Huizinga suggests in [24].

This question was included in the beta-testing logic, described above.

6

Concluding Remarks

Ascription of the Present Study

Having made an extensive literature review i have come across several studies that have been focused on educational video game and their effects in K12 classrooms, but only two of them examined the side of teachers (Demirbilek [37] and Kebreitchi et al[43]). Those studies focused on the beliefs of teachers about video games and their effect in the classroom.

This current study follows the main direction of those studies but differentiates being based on its exceptional, unique if i may say, sample which is its main power. Upon this sample i have attempted to investigate beliefs of those highly trained and experienced (educationally) teachers towards VG implementation and the possible obstacles along the way but also to examine the improvement of them, if any, with a pre/post test module and a gaming session intervention.

I thus want to believe that maybe i am contributing a tiny pixel in the "infinite" image of Video Games in Education by completing it.

Brief Results and Conclusions

The quantitative analysis on the results of the pre and post tests suggest that indeed there was a significant improvement of the participants that improved their scores from pre to post test in this mathematically-versed sample.

The data that arose from the open-ended questionnaires were overwhelming and i tried to find my way through a mix of quantitative and qualitative analysis. Some of the results that i consider to be significant were that the majority of the participants:

- valued the importance of MC in education despite considering themselves poor in them
- pled ignorance concerning EVGs
- was positively disposed to the idea of VGs in education and to what it entails
- advocated for fun orientation of educational video games
- was satisfied by playing NNG though acknowledging that the game could not be attention-grasping and motivating for a long time duration especially for students and also that it suitably promoted MCs

- reported negative emotions i.e. fatigue/stress while playing the game
- did not consider NNG's intrinsic goal motivating enough in contrast with the extrinsic one

  Specifically concerning the city creation goal the players did not considered the goal as an engaging one and many of them did not even acknowledged it as a goal. As for the extrinsic goal of medal acquisition, the majority of participants found it motivating, and many of them explicitly mentioned that it was the only target they had in the game.
- would use the game in their classrooms complementary or as homework
- considered NNG to be of easy to normal difficulty

Limitations of the study

As i have extensively discussed above in order to have generalizable quantitative results, a control group with the same specificities i.e. mathematics abilities, education experience, keen interest in education and also the same magnitude was needed. Hence it is better to consider the above result as an indication that the game actually works towards the improvement rather than a causal relationship. Further research is needed in order to determine causality.

Another reason that led us to this decision was, as i described in the specific chapter, the duration of the gaming session which was one fifth of the time the Finnish team used (10h).

The qualitative results i.e. the open-ended questionnaire analysis part of the study, i think, can fairly represent a developing country's workforce in the field of Education in terms of what they're thinking towards and what obstacles can somebody come across, implementing VGs in education.

Critique of the Game and What's Next

The game is a good attempt to make an educational game from the Finnish Team. As i have mentioned across many parts of this study and as the participants suggest there are many good features: math content integration, simple basic concept, easy to learn and master, exercising reverse operations and honing the strategic and optimization reasoning skills of the players, naming my favorites. The game lacks a lot of things though from gamification features to a decent and engaging goal or an adaptive artificial in-game intelligence that would respond while evaluating your skills depending on the input.

I want to make a suggestion though i cannot imagine how it can be carried out. A good idea that VG education should be steered to is for new mathematical EVGs to break the symbol barrier as Devlin has defined it, something that NN although integrated as a game does not achieve. This does not necessarily mean that the main concept of the game should be altered but merely that the ways of representing the math content and the way the player gives input should differentiated. Of course the subject matter is not an easy one, i can merely propose a vague change in the game's input following the steps of Devlin's Wuzzit where the player inputs the numbers and the operations by moving wheels.

I want to highlight two main issues, as i perceive them, that are innate to NN's quintessence and if a way to surpass them was to be found, i think that the game's prospectives and potential would be greatly boosted.

The first issue concerns the engagement entailed by the game. As this study's results suggest the great majority of professionally trained and highly experience mathematics educators considered the goals of the game weak and the game itself too trivial and monotonous to be engaging for more than a few game sessions. But even if we only want to use NN for a few game sessions or complementary as homework material we must consider the strong competition that it has from other educational and commercial video games. Engagement is the key component of a good video game as bibliography suggest, to quote again a participant "if the game is not engaging, the students won't play it".

Last but not least the game as it is lacks in the representation of division. I don't mean this graphicwise but in deeper and more conceptual way. Of course addition and subtraction of numbers can be successfully represented by the lines that the ship makes. Multiplication can also be viewed as a linear operation of addition so there is no problem there either. The problem is in the representation concerns the division where there is no direct link between the signifier (the representation of division in-game) and the signified (the actual division). The only idea that i can think of is a representation in the direction of the euclidean algorithm as it is describe in Euclidean Elements (for reference you can see Heath's Euclidean Elements[59]), i again have no valid proposal though, for an in-game implementation.

If a cheap way, not only fundingwise but also workloadwise, can be found to improve the game and incorporate ways to surpass the main issues described above and of course to include the many ideas of the participants as they have been extensively presented in the Qualitative Results Chapter, then i believe that the game holds potential for a future game implementation in education.

I am puzzled though, having seen the papers of the Finnish Team [10, 21] where their results do not suggest any substantial gains for the students that participated in the game sessions contrasting the control group. Maybe there needs to be a study where the control group would be carefully designed in order to find if in fact there is a significant difference between pre and post test results.

Of course if the results of the game gains remain low then EVGs that hold more promise should be promoted as Gee quotes the survival of video games is a capitalist-driven Darwinian process of selection of the fittest[20].

Video Games in Education have come a long way from Papert's 1967 Logo until today and have much distance to cover until the final destination, but i believe that they holds true potential to revolutionize education always following the everything in moderation moto.

We must also keep in mind as Gaudreault and Marion have extensively analyzed in [5] that every new medium is born twice: once when it is used for the first time in order to translate earlier practices and a second time when the specificities of the new medium are acknowledged. The first train has come and gone so now we are ready to get on the second one the one that will exploit the potential of the new video game medium.

As Prensky remarks the reason computer games are so engaging is because the primary objective of the game designer is to keep the user engaged. The goal of keeping users (i.e. learners) engaged is, of course, not the primary concern of educators. The primary goal of educators is to instruct, i.e. to get the material across.

The challenge we are facing is to compromise educators and game designers in order

to create educational video games in whom at the very least the learner will remain self-motivated and ideally will enjoy and have great gains from the process.

Epilogue

Of course anybody that has reached this far in this thesis will have understood by now that i am pro video games in education, but let me take a stance here to elucidate my point of view. EVG hold, i believe, true potential to change education however if their implementation is carried out blindly and impetuously, i can think of many dangers that might be brought upon us. This implementation should be done following the light of principled research and not the mercenary motives of the big conglomerates that see an opportunity to exploit. I can only hope that the need for better education will prevail over monetary incentives.

Last but not least i want to close with this. It may seem that in the present study i am just beta testing the NNG and maybe i am actually doing, just this. What matters though is what i have gained, and i have gained, from this process, as the Greek poet Constantine Kavafy concludes in his poem what matters is not the destination but merely the journey[30].

> Keep Ithaka always in your mind. Arriving there is what you are destined for. But do not hurry the journey at all. Better if it lasts for years, so you are old by the time you reach the island, wealthy with all you have gained on the way, not expecting Ithaka to make you rich.
> Ithaka gave you the marvelous journey. Without her you would not have set out. She has nothing left to give you now.
> And if you find her poor, Ithaka won't have fooled you. Wise as you will have become, so full of experience, you will have understood by then what these Ithakas mean.

7

Appendix A Gee's Learning Principles

The good learning principles of Gee that are supposed to be incorporated in good games! Here i include an exact copy of the 36 learning principles.

THE 36 LEARNING PRINCIPLES

1. **Active, Critical Learning Principle**

   All aspects of the learning environment (including the ways in which the semiotic domain is designed and presented) are set up to encourage active and critical, not passive, learning. Mathematics as Devlin puts it is not a spectator sport!

2. **Design Principle**

   Learning about and coming to appreciate design and design principles is core to the learning experience.

3. **Semiotic Principle**

   Learning about and coming to appreciate interrelations within and across multiple sign systems (images, words, actions, symbols, artifacts, etc.) as a complex system is core to the learning experience.

4. **Semiotic Domains Principle**

   Learning involves mastering, at some level, semiotic domains, and being able to participate, at some level, in the affinity group or groups connected to them.

5. **Metalevel Thinking about Semiotic Domains Principle**

   Learning involves active and critical thinking about the relationships of the semiotic domain being learned to other semiotic domains.

6. **"Psychosocial Moratorium" Principle**

   Learners can take risks in a space where real-world consequences are lowered. According to Devlin even professional mathematicians are wrong almost all the time! This is not to say that professional mathematicians like failure. No one likes to fail. Rather, mathematicians have learned that the path to eventual success is almost always littered with failures. The occasional successes are what make it worth the

effort. The trick is to live with failure, to regard it as part of the process, and to learn from each mistake. This points out one of the main problems with tests; they rarely allow for a second attempt, or a third, or however many it takes. They do not test if someone can do math; they determine if a person can do math within a specific period of time and get it right at the first attempt.

7. **Committed Learning Principle**

   Learners participate in an extended engagement (lots of effort and practice) as extensions of their real-world identities in relation to a virtual identity to which they feel some commitment and a virtual world that they find compelling.

   Devlin comments that there is a fascinating identity shift that goes on in video games that educators can greatly advantage of. In game your identity is your game character. This means that failure is not as personal as it is in real life; the player can mitigate failure to his/her game character even though he/she is the one who controls the character.

   In many video games, when you really screw up, your character gets killed. But obviously, the game designer did not want you to stop playing. Thus, "death" in a video game is not a permanent thing; there is always the option of resurrection. In early games, this often meant you started out afresh, or at least you started out at the beginning of some previously attained threshold level or a checkpoint if you will. This meant that although death was not permanent the cost of being killed was high and this results in an extremely cautious approach adopted by players.

8. **Identity Principle**

   Learning involves taking on and playing with identities in such a way that the learner has real choices (in developing the virtual identity) and ample opportunity to meditate on the relationship between new identities and old ones. There is a tripartite play of identities as learners relate, and reflect on, their multiple real-world identities, a virtual identity, and a projective identity.

9. **Self-Knowledge Principle**

   The virtual world is constructed in such a way that learners learn not only about the domain but about themselves and their current and potential capacities.

10. **Amplification of Input Principle**

    For a little input, learners get a lot of output. Devlin quotes the greater the positive output for a given input, the greater the incentive to repeat that kind of input

11. **Achievement Principle**

    For learners of all levels of skill there are intrinsic rewards from the beginning, customized to each learner's level, effort, and growing mastery and signaling the learner's ongoing achievements.

12. **Practice Principle**

    Learners get lots and lots of practice in a context where the practice is not boring (i.e., in a virtual world that is compelling to learners on their own terms and where the learners experience ongoing success). They spend lots of time on task. In math

as in most other aspects of live, practice makes perfect and a fascinating feature of video games is how they make repetitive actions seem fun.

13. **Ongoing Learning Principle**

    The distinction between learner and master is vague, since learners, thanks to the operation of the "regime of competence" principle listed next, must, at higher and higher levels, undo their routinized mastery to adapt to new or changed conditions. There are cycles of new learning, automatization, undoing automatization, and new reorganized automatization.

14. **"Regime of Competence" Principle**

    The learner gets ample opportunity to operate within, but at the outer edge of, his or her resources, so that at those points things are felt as challenging but not "undoable".

15. **Probing Principle**

    Learning is a cycle of probing the world (doing something); reflecting in and on this action and, on this basis, forming a hypothesis; reprobing the world to test this hypothesis; and then accepting or rethinking the hypothesis.

16. **Multiple Routes Principle**

    There are multiple ways to make progress or move ahead. This allows learners to make choices, rely on their own strengths and styles of learning and problem solving, while also exploring alternative styles.

17. **Situated Meaning Principle**

    The meanings of signs (words, actions, objects, artifacts, symbols, texts, etc.) are situated in embodied experience. Meanings are not general or decontextulized. Whatever generality meanings come to have is discovered bottom up via embodied experiences.

18. **Text Principle**

    Texts are not understood purely verbally (i.e., only in terms of the definitions of the words in the text and their text-internal relationships to each other) but are understood in terms of embodied experiences. Learners move back and forth between texts and embodied experiences. More purely verbal understanding (reading texts apart from embodied action) comes only when learners have had enough embodied experience in the domain and ample experiences with similar texts.

19. **Intertextual Principle**

    The learner understands texts as a family ("genre") of related texts and understands any one such text in relation to others in the family, but only after having achieved embodied understandings of some texts. Understanding a group of texts as a family (genre) of texts is a large part of what helps the learner make sense of such texts. In math education the different genres would be the different branches of math (algebra, geometry, statistics, etc.)

20. **Multimodal Principle**

    Meaning and knowledge are built up through various modalities (images, texts, symbols, interactions, abstract design, sound, etc.), not just words.

21. **"Material Intelligence" Principle**

    Thinking, problem solving, and knowledge are "stored" in material objects and the environment. This frees learners to engage their minds with other things while combining the results of their own thinking with the knowledge stored in material objects and the environment to achieve yet more powerful effects.

22. **Intuitive Knowledge Principle**

    Intuitive or tacit knowledge built up in repeated practice and experience, often in association with an affinity group, counts a great deal and is honored. Not just verbal and conscious knowledge is rewarded.

23. **Subset Principle**

    Learning even at its start takes place in a (simplified) subset of the real domain. In other words a real world environment.

24. **Incremental Principle** Learning situations are ordered in the early stages so that earlier cases lead to generalizations that are fruitful for later cases. When learners face more complex cases later, the learning space (the number and type of guesses the learner can make) is constrained by the sorts of fruitful patterns or generalizations the learner has found earlier.

25. **Concentrated Sample Principle**

    The learner sees, especially early on, many more instances of fundamental signs and actions than would be the case in a less controlled sample. Fundamental signs and actions are concentrated in the early stages so that learners get to practice them often and learn them well.

26. **Bottom-up Basic Skills Principle**

    Basic skills are not learned in isolation or out of context; rather, what counts as a basic skill is discovered bottom up by engaging in more and more of the game/domain or game/domains like it. Basic skills are genre elements of a given type of game/domain.

27. **Explicit Information On-Demand and Just-in-Time Principle**

    The learner is given explicit information both on-demand and just-in-time, when the learner needs it or just at the point where the information can best be understood and used in practice.

28. **Discovery Principle** Overt telling is kept to a well-thought-out minimum, allowing ample opportunity for the learner to experiment and make discoveries. As Keith quote the old adage "You tell me and i forget; you show me and i remember; you let me discover and i know".

29. **Transfer Principle**

    Learners are given ample opportunity to practice, and support for, transferring what they have learned earlier to later problems, including problems that require adapting and transforming that earlier learning. Devlin quotes Jean Lave and says that true context to context transfer is not really possible because everything is situated. In math effective transfer is made possible by the process of abstraction, which allows us to look for relations and structures that are similar.

30. **Cultural Models about the World Principle**

    Learning is set up in such a way that learners come to think consciously and reflectively about some of their cultural models regarding the world, without denigration of their identities, abilities, or social affiliations, and juxtapose them to new models that may conflict with or otherwise relate to them in various ways.

31. **Cultural Models about Learning Principle**

    Learning is set up in such a way that learners come to think consciously and reflectively about their cultural models of learning and themselves as learners, without denigration of their identities, abilities, or social affiliations, and juxtapose them to new models of learning and themselves as learners.

32. **Cultural Models about Semiotic Domains Principle**

    Learning is set up in such a way that learners come to think consciously and reflectively about their cultural models about a particular semiotic domain they are learning, without denigration of their identities, abilities, or social affiliations, and juxtapose them to new models about this domain.

33. **Distributed Principle**

    Meaning/knowledge is distributed across the learner, objects, tools, symbols, technologies, and the environment.

34. **Dispersed Principle**

    Meaning/knowledge is dispersed in the sense that the learner shares it with others outside the domain/game, some of whom the learner may rarely or never see face-to-face.

35. **Affinity Group Principle**

    Learners constitute an "affinity group", that is, a group that is bonded primarily through shared endeavors, goals, and practices and not shared race, gender, nation, ethnicity, or culture.

36. **Insider Principle**

    The learner is an "insider", "teacher", and "producer" (not just a "consumer") able to customize the learning experience and domain/game from the beginning and throughout the experience.

8

Appendix B1 Pre and Post Test Data

Participant Number	Gender	Age Group	Education Degree	Education Experience	Computer Use	VideoGame Use	Education Practice
1	0	1	1	1	2	2	4
2	0	0	1	2	1	0	3
3	0	0	1	2	1	0	2
4	1	0	1	1	1	0	3
5	1	1	1	0	2	1	3
6	0	1	1	1	2	0	3
7	0	1	1	0	2	0	4
8	0	1	1	1	2	0	3
9	0	1	1	0	1	1	3
10	1	0	1	2	2	0	3
11	0	1	1	0	2	1	3
12	0	1	1	1	2	2	3
13	1	1	1	0	2	0	3
14	1	1	1	1	2	1	3
15	0	1	1	0	2	2	3
16	0	1	1	1	2	2	4

Figure 8.1: Demographics

Participant Number	PreOpen1	PreOpen2	PreOpen3	PreOpen4	PreOpenTotal	PreOpenTotal_Adapted
1	4	1,5	3,5	4	13	195
2	4	4	4	3	15	225
3	4	0	0	4	8	120
4	3	4	4	3	14	210
5	3	2	4	0	9	135
6	4	1,5	2,5	4	12	180
7	2	3	2	2	9	135
8	1,5	1,5	4	3	10	150
9	4	1,5	1,5	0	7	105
10	2	4	3,5	3	12,5	187,5
11	3,5	2	3	3	11,5	172,5
12	4	3	3	3,5	13,5	202,5
13	3	2	4	1,5	10,5	157,5
14	4	2	3	3,5	12,5	187,5
15	3	4	4	2	13	195
16	4	2	3,5	3,5	13	195

Figure 8.2: Pre Test Open Problems

Participant Number	PreCon1	PreCon2	PreCon3	PreCon4	PreCon5	PreConTotal	PreConTotal_Adapted	Extra Time
1	1	1	0	0	0	2	96	-
2	0	1	0	0	0	1	48	-
3	1	0	0	1	1	3	144	-
4	0	1	0	0	0	1	48	-
5	0	0	0	0	0	0	0	-
6	1	1	0	0	0	2	96	-
7	1	1	1	1	0	4	192	-
8	0	0	1	0	1	2	96	-
9	1	1	0	0	0	2	96	-
10	1	1	1	0	0	3	144	-
11	1	1	1	1	1	5	240	-
12	1	0	1	0	1	3	144	-
13	1	1	0	0	0	2	96	-
14	1	1	1	1	1	5	240	-
15	1	0	1	0	0	2	96	-
16	0	0	0	0	0	0	0	-

Figure 8.3: Pre Test Constrained Problems

Participant Number	PreMulti1	PreMulti2	PreMulti3	PreMulti4	PreMulti5	PreMulti6	PreMulti7	PreMulti8	PreMulti9	PreMulti10	PreMulti11	PreMulti12	PreMultiTotal	PreMultiTotal_Adapted	Extra Time
1	1	1	1	0	0	1	0	0	0	1	1	0	6	120	-
2	1	1	1	0	1	1	0	1	0	0	0	0	6	120	-
3	1	1	1	1	0	0	0	0	1	0	1	1	7	140	-
4	0	1	1	1	1	1	1	1	1	1	1	1	11	220	-
5	1	1	1	1	1	0	0	0	0	0	0	0	5	100	-
6	1	1	1	1	1	1	1	0	1	1	0	0	9	180	-
7	1	1	1	1	1	1	1	0	0	0	0	0	7	140	-
8	1	1	0	1	1	1	1	0	0	0	0	0	6	120	-
9	1	1	1	0	0	1	1	1	0	0	0	0	6	120	-
10	1	1	1	1	1	1	1	1	0	1	0	0	9	180	-
11	0	1	0	0	1	1	0	0	0	0	1	0	4	80	-
12	1	1	1	1	1	1	1	1	1	1	0	1	11	220	30sec
13	1	1	1	0	1	1	1	1	1	1	1	1	11	220	-
14	1	1	1	1	1	1	0	0	0	0	0	0	6	120	-
15	1	1	1	1	1	0	0	0	0	0	0	0	5	100	-
16	1	1	1	1	1	1	0	1	0	0	0	0	7	140	-

Figure 8.4: Pre Test Multiple Problems

Participant Number	PostOpen1	PostOpen2	PostOpen3	PostOpen4	PostOpenTotal	PostOpenTotal_Adapted
1	3,5	3,5	4	4	15	225
2	3,5	3,5	1,5	3,5	12	180
3	3,5	3,5	4	3,5	14,5	217,5
4	3,5	3	4	3,5	14	210
5	3,5	2,5	3	0	9	135
6	4	2,5	1,5	3,5	11,5	172,5
7	3,5	1,5	3	4	12	180
8	3,5	3	1,5	0	8	120
9	3,5	3,5	3,5	4	14,5	217,5
10	4	4	1,5	0	9,5	142,5
11	4	4	1,5	1,5	11	165
12	4	3,5	3,5	4	15	225
13	3,5	3	3	4	13,5	202,5
14	4	4	4	4	16	240
15	4	4	3,5	1,5	13	195
16	3,5	3	0	0	6,5	97,5

Figure 8.5: Post Test Open Problems

Participant Number	PostCon1	PostCon2	PostCon3	PostCon4	PostCon5	PostConTotal	PostConTotal_Adapted	Extra Time
1	1	1	1	1	1	5	240	30sec
2	0	1	1	1	0	3	144	-
3	1	0	1	0	1	3	144	-
4	0	1	1	0	0	2	96	-
5	1	1	1	0	0	3	144	-
6	0	1	1	1	1	4	192	-
7	1	1	1	1	1	5	240	-
8	0	1	1	0	0	2	96	-
9	0	1	0	1	1	3	144	-
10	1	1	1	1	0	4	192	-
11	1	1	1	1	1	5	240	-
12	0	1	0	0	0	1	48	-
13	1	1	1	0	0	3	144	-
14	1	1	1	1	1	5	240	-
15	0	1	1	1	0	3	144	-
16	1	0	1	1	1	4	192	-

Figure 8.6: Post Test Constrained Problems

Participant Number	PostMulti1	PostMulti2	PostMulti3	PostMulti4	PostMulti5	PostMulti6	PostMulti7	PostMulti8	PostMulti9	PostMulti10	PostMulti11	PostMulti12	PostMultiTotal	PostMultiTotal_Adapted	Extra Time
1	1	1	1	1	1	1	1	1	1	1	0	1	11	220	140sec
2	1	1	0	1	1	1	1	1	1	1	1	1	11	220	-
3	1	1	1	1	1	1	1	1	0	0	0	0	8	160	-
4	1	1	1	1	1	1	1	1	1	1	1	1	12	240	40sec
5	1	1	0	0	0	0	0	0	0	0	1	0	3	60	-
6	1	1	1	1	1	1	1	1	1	1	0	1	11	220	-
7	1	1	1	0	1	1	1	1	1	1	0	1	10	200	-
8	1	1	1	1	1	1	1	1	1	1	1	1	12	240	-
9	1	1	1	1	1	1	1	1	1	1	1	1	12	240	20sec
10	1	1	1	1	1	1	1	1	1	1	1	0	11	220	-
11	1	0	0	0	1	0	1	0	0	0	0	0	3	60	-
12	1	0	1	0	1	1	1	1	1	1	1	1	10	200	145sec
13	1	1	1	0	1	1	1	1	1	1	0	1	10	200	145sec
14	1	1	0	0	1	1	0	1	1	1	1	1	9	180	-
15	1	1	1	0	1	1	1	1	1	1	1	1	11	220	-
16	1	1	1	0	1	1	1	1	1	1	1	1	10	200	40sec

Figure 8.7: Post Test Multiple Choice Problems

Participant Number	Stages Played Total	Energy Stages	Motion Stages	Gold Medals	Silver Medals	Bronze Medals	Time Played the Game	Gaming Quality Index
1	14	5	9	9	3	2	2hours	44
2	9	6	3	5	2	2	2hours	26
3	8	5	3	4	3	1	2hours	23
4	20	11	9	14	2	4	3hours 30	
5	6	4	2	6	0	0	2hours	24
6	9	4	5	6	1	2	2hours	28
7	13	4	9	12	1	0	2hours	50
8	13	4	9	12	1	0	2hours	50
9	15	5	10	13	1	1	2hours 50	55
10	9	3	6	4	4	1	2hours	25
11	5	3	2	4	1	0	2hours	18
12	8	3	5	6	2	0	2hours	28
13	12	3	9	12	0	0	2hours	48
14	7	4	3	6	1	0	2hours	26
15	7	4	3	6	1	0	2hours	26
16	6	4	2	2	3	1	2hours	15

Figure 8.8: Game Sessions Results

Participant Number	Energy Stages	Motion Stages	Preferred Gaming Mode
1	5	9	Moves
2	6	3	Energy
3	5	3	Energy
4	11	9	Energy
5	4	2	Energy
6	4	5	Moves
7	4	9	Moves
8	4	9	Moves
9	5	10	Moves
10	3	6	Moves
11	3	2	Energy
12	3	5	Moves
13	3	9	Moves
14	4	3	Energy
15	4	3	Energy
16	4	2	Energy

Figure 8.9: Game Mode Preference Analytic Data

9

Appendix B2 Quantitative Results

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
PreTotal_Adapted	415,88	83,701	12
PostTotal_Adapted	546,63	92,568	12

Correlations

		PreTotal_Adapted	PostTotal_Adapted
PreTotal_Adapted	Pearson Correlation	1	,786**
	Sig. (2-tailed)		,002
	N	12	12
PostTotal_Adapted	Pearson Correlation	,786**	1
	Sig. (2-tailed)	,002	
	N	12	12

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 9.1: Descriptive Statistics and Pearson Correlation for PreTotalAdapted and PostTotalAdapted Scores

Nonparametric Correlations

Correlations

			PreTotal_Adapted	PostTotal_Adapted
Kendall's tau_b	PreTotal_Adapted	Correlation Coefficient	1,000	,545*
		Sig. (2-tailed)	.	,014
		N	12	12
	PostTotal_Adapted	Correlation Coefficient	,545*	1,000
		Sig. (2-tailed)	,014	.
		N	12	12
Spearman's rho	PreTotal_Adapted	Correlation Coefficient	1,000	,713**
		Sig. (2-tailed)	.	,009
		N	12	12
	PostTotal_Adapted	Correlation Coefficient	,713**	1,000
		Sig. (2-tailed)	,009	.
		N	12	12

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 9.2: Kendall's Tau and Spearman's Rho Correlation for PreTotalAdapted and PostTotalAdapted Scores

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
PreTotal_Adapted	12	415,8750	83,70107	235,00	547,50
PostTotal_Adapted	12	546,6250	92,56819	339,00	685,00

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
PostTotal_Adapted - PreTotal_Adapted	Negative Ranks	0[a]	,00	,00
	Positive Ranks	12[b]	6,50	78,00
	Ties	0[c]		
	Total	12		

a. PostTotal_Adapted < PreTotal_Adapted

b. PostTotal_Adapted > PreTotal_Adapted

c. PostTotal_Adapted = PreTotal_Adapted

Test Statistics[a]

	PostTotal_Adapted - PreTotal_Adapted
Z	-3,059[b]
Asymp. Sig. (2-tailed)	,002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Figure 9.3: Wilcoxon Matched Pairs Sign Ranked Test

10

Appendix B3 Research Design

In this Chapter i am juxtaposing the full form of Pre and Post tests and also the form of the digital open-ended and demographics questionnaires.

Open

Try to ***make as many different combinations*** *in order to get the requested number (dark grey rectangular frame). You can use only the numbers in the box(light grey frame). You can use each number as many times as you want. You can use all the operations (addition, subtraction, multiplication, and division) and as many times as you want.*

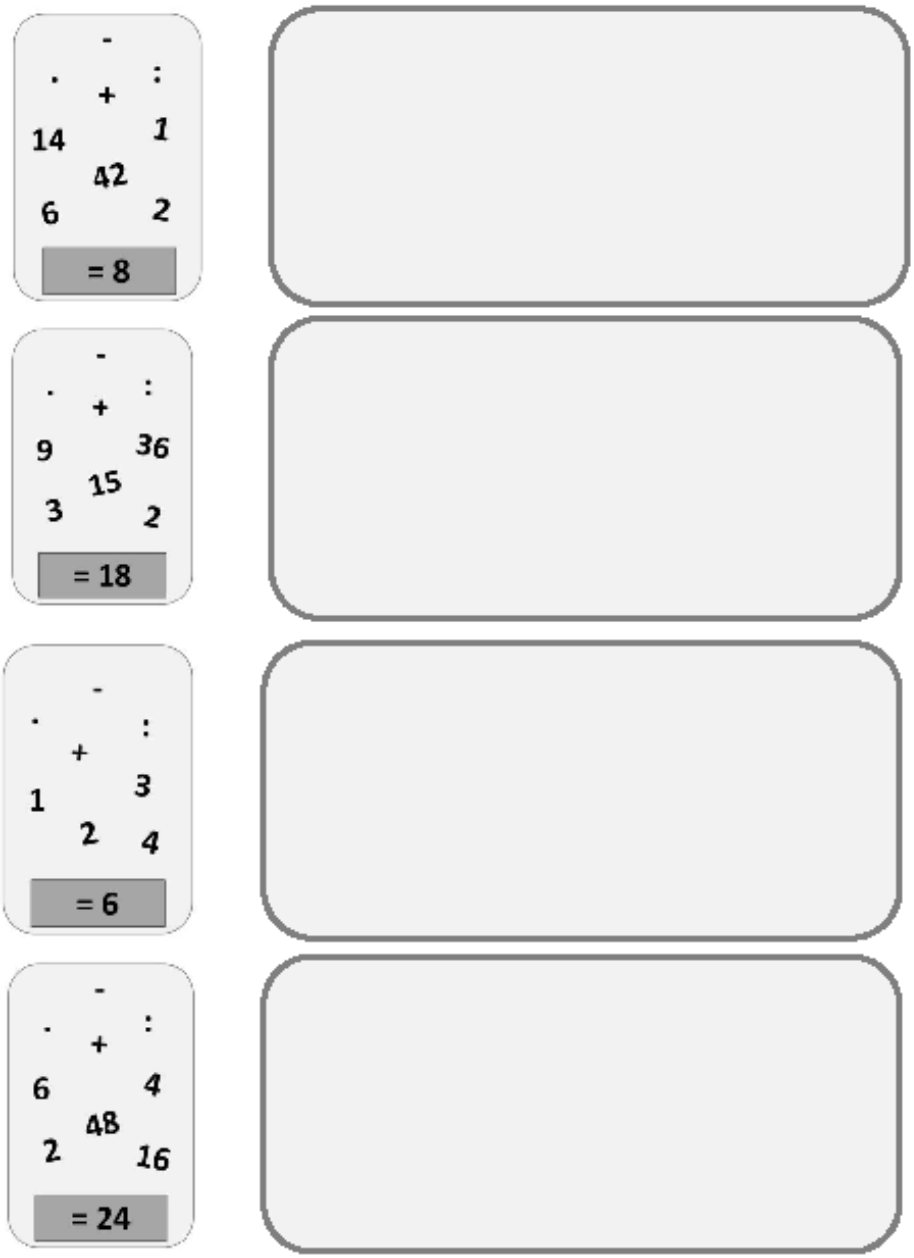


Figure 10.1: PreTest Page 1

PRETEST

2

Constrained

Initiate from the starting number and figure out how to get to the wanted number using each time the allowed operations and the allowed numbers. You can write your solution in the grey frame.

Example:

Starting number: 98

Wanted number: 54

Allowed numbers: 1,2,3,5,7

Allowed operations: + , - , · , :

Possible Solution:

98:2=49+5=54

1.

Starting number: 99

Wanted number: 76

Allowed numbers: 3,4,5

Allowed operations: + , - , · , :

2. *Starting number: 76*

Wanted number: 6

Allowed numbers: 1,3,4

Allowed operations: - , :

Figure 10.2: PreTest Page 2

PRETEST

3

3. *Starting number: 98*

Wanted number: 40

Allowed numbers: 2,3,7

Allowed operations: - , · , :

4. *Starting number: 65*

Wanted number: 8

Allowed numbers: 1,8

Allowed operations: -, ·

5. *Starting number: 80*

Wanted number: 10

Allowed numbers: 2,3,4,6

Allowed operations: + , - , :

Figure 10.3: PreTest Page 3

PRETEST

4

Multiple Choice & Fill-in Questions

Conceptual: *Read the following questions and circle the correct answer. The correct answer exists every time and it is unique. Priority of operations holds, as it is known, in every item.*

1. Which of the following equals: 28 : 2 - 3?
   a. 26 : 2 - 3
   b. 24 : 2 + 1
   c. 26 : 2 - 2
   d. None of the above

2. Does the equation ((7 · 11 + 3) : 4) · 5 = 110 hold?
   a. Yes
   b. No

3. Which of the following equals: 97 + 97 + 97 + 97 + 97 ?
   a. 4 · 97 + 194
   b. 388 + 90
   c. 97 · 3 + 193
   d. None of the above

4. If the equation : 11 · 26 = 286 is correct, which of the following equations is also correct?
   a. 143 : 13 = 11
   b. 286 : 11 = 28
   c. 12 · 25 = 286
   d. None of the above

Figure 10.4: PreTest Page 4

PRETEST

5

Equations Multi: *Choose which number goes in the empty space so that the equation holds. The correct answer exists every time and it is unique. Priority of operations holds, as it is known, in every item.*

A. $(37 \cdot 7) - 30 + 1 = \_\_\_ \cdot 10$

a. 17
b. 26
c. 23
d. 19

B. $((\_\_\_ : 3) + 6) \cdot 5 = 29 \cdot 5$

a. 72
b. 66
c. 69
d. 75

C. $((3 \cdot 18) - 21) \cdot 3 - 40 = 177 : \_\_\_$

a. 7
b. 3
c. 11
d. 13

D. $(16 \cdot 7) : 2 + 8 = \_\_\_ : 4$

a. 240
b. 256
c. 264
d. 244

Figure 10.5: PreTest Page 5

PRETEST

6

Equations Fill-in: *Write the suitable number in the empty space so that the equation holds. Priority of operations holds, as it is known, in every item.*

A. 13 · 9 = 234 : ___

B. 115 - 46 = 3 · ___

C. 13 + ___ = 75 + 17

D. 71 + 13 = 588 : ___

Figure 10.6: PreTest Page 6

Open

Try to ***make as many different combinations*** *in order to get the requested number (dark grey rectangular frame). You can use only the numbers in the box(light grey frame). You can use each number as many times as you want. You can use all the operations (addition, subtraction, multiplication, and division) and as many times as you want.*

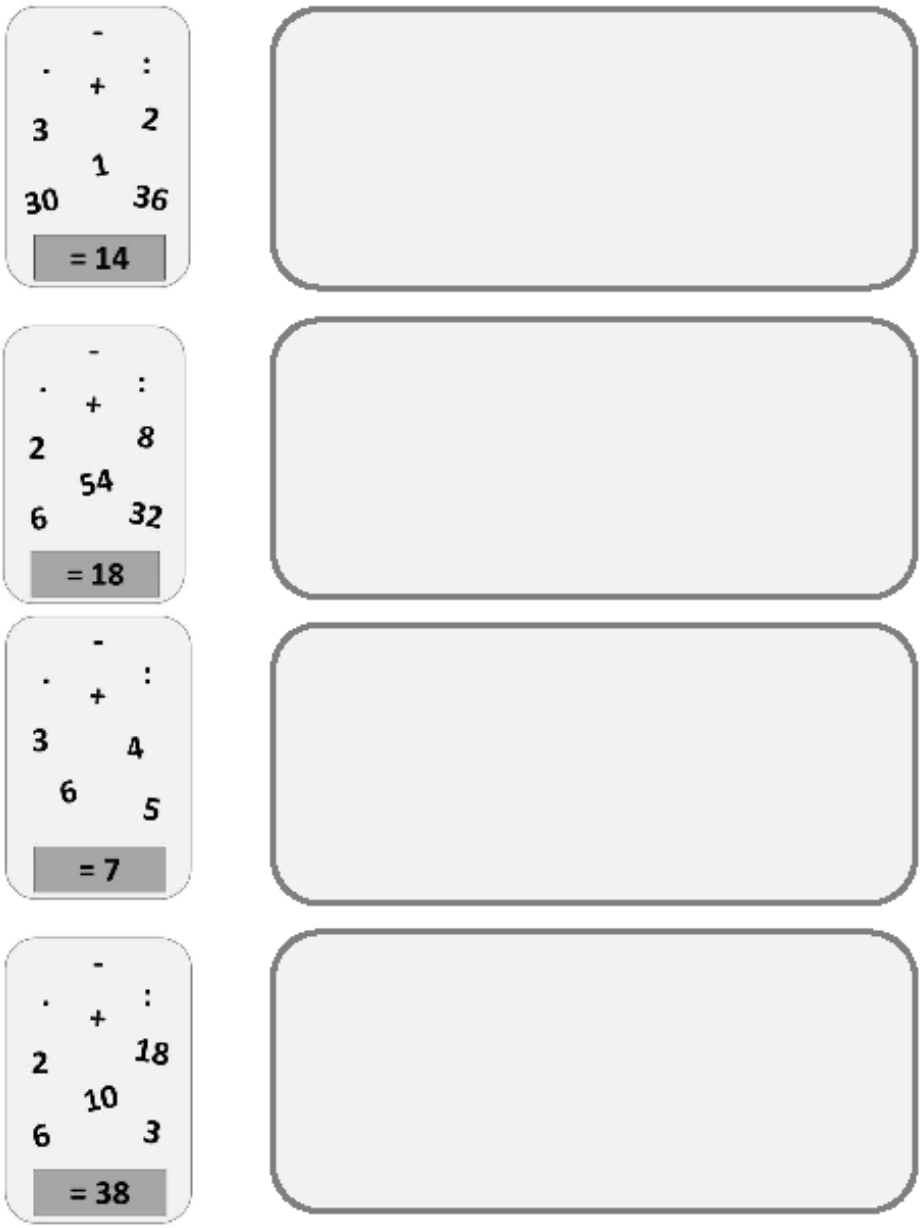


Figure 10.7: PostTest Page 1

POSTTEST

2

Constrained

Initiate from the starting number and figure out how to get to the wanted number using each time the allowed operations and the allowed numbers. You can write your solution in the grey frame.

Example:

Starting number: 98

Wanted number: 54

Allowed numbers: 1,2,3,5,7

Allowed operations: + , - , · , :

Possible Solution:

98:2=49+5=54

1. *Starting Number: 88*

Wanted Number: 25

Allowed Numbers: 1,3,4

Allowed Operations: - , :

2. *Starting Number: 32*

Wanted Number: 19

Allowed Numbers: 2,3

Allowed Operations: + , :

Figure 10.8: PostTest Page 2

POSTTEST

3

3. *Starting Number: 81*

Wanted Number: 32

Allowed Numbers: 3,5

Allowed Operations: + , :

4. *Starting Number: 83*

Wanted Number: 6

Allowed Numbers: 1,2,7

Allowed Operations: + , :

5. *Starting Number: 59*

Wanted Number: 97

Allowed Numbers: 1,3,5

Allowed Operations: + , - , · , :

Figure 10.9: PostTest Page 3

POSTTEST

4

Multiple Choice & Fill-in Questions

Conceptual: *Read the following questions and circle the correct answer. The correct answer exists every time and it is unique. Priority of operations holds, as it is known, in every item.*

1. Does the equation ((93 - 8 - 3) : 2 = 42 hold?
   a. Yes
   b. No

2. If the equation : 89 + 135 + 67 = 291 is correct, which of the following equations is also correct?
   a. 89 + 135 + 135 = 291 – 67 – 135
   b. 67 + 135 – 291 = 291 – 89
   c. 89 + 135 - 67 = 291
   d. None of the above

3. Does the equation ((97 - 8) · 3) + 7) : 2 = 137 hold?
   a. Yes
   b. No

4. Which of the following equals: 34 : 2 - 3?
   a. 7 · 2 + 2
   b. 98 : 7 - 4
   c. 105 : 7 - 1
   d. None of the above

Figure 10.10: PostTest Page 4

POSTTEST

5

Equations Multi: *Choose which number goes in the empty space so that the equation holds. The correct answer exists every time and it is unique. Priority of operations holds, as it is known, in every item.*

A. ___ : 2 + 1 = 17 + 25

a. 88
b. 82
c. 78
d. 64

B. (26 : 2 – 3) · 3 – 1 = ___ + 12

a. 17
b. 19
c. 18
d. 16

C. ((61 + 1) : 2 + 1) : 8 = ___ : 11

a. 33
b. 66
c. 55
d. 44

D. (___ - 1) : 2 + 2 = 23 · 2

a. 93
b. 87
c. 84
d. 89

Figure 10.11: PostTest Page 5

POSTTEST

6

Equations Fill-in: *Write the suitable number in the empty space so that the equation holds. Priority of operations holds, as it is known, in every item.*

A. 73 + ___ = 23 + 91

B. 89 – 43 = 2 · ___

C. ___ · 4 = 304 : 2

D. 138 – ___ = 296 :4

Figure 10.12: PostTest Page 6

About Mental Calculations

Explain the term mental calculations

1. Do you think that you are good in mental calculations? If yes why? If not why? Elaborate.
2. Do you consider mental calculations important in the field of math education?
3. In your classroom would/do you teach towards achieving a mental calculations skill? If yes how?
4. Would you say that NN promotes in an appropriate way mental calculations? If yes how? If no how? Elaborate.

About The Games in Education - Beliefs

1. Have you ever played computer games? Elaborate!
2. Have/Would you used/use Educational Video Games in your Classroom? If not elaborate on your reasons. What obstacles do you think you find/would find? Would you enjoy teaching a course this way?
3. Do you think it is good or bad for educational video games to be fun oriented? Elaborate.
4. What is your position towards the implementation of video games in education?
5. Do you think that any of the subjects taught in schools is more appropriate to be taught through video games?
6. Do you believe that there is a difference between male and female video game players? Elaborate.

NumberNavigation (NN)

1. Did you enjoy playing the game? Why or why not?
2. Did you employ any mathematical skills, concepts or processes while playing the game? What were those?
3. While playing the game did you observed any anxiety, tiredness or need for confirmation of any kind?
4. Did you found the game motivating? Would you have played it in your own time?
5. Did you think that the in game - necessity to build a city, through the collection of materials, would be motivating enough (presents an appropriate level of challenge) for students?
6. Was it easy to be concentrated in the game? After how long did the game tire you (if it did)?
7. Do you think that this game can catch a student's attention/interest?
8. Would you use this game as a supplemental tool/material in your classroom and/or as take-home practice for your students?
9. How you would characterize the game's difficulty? Explain.
10. In your opinion what aspects of the game were the most engaging/fun?
11. Are there any expansions/modifications to the game that you would recommend?
12. Would you play NN aiming to finish it?

Do you have anything else to add, suggest or comment?

Figure 10.13: Digital Open-ended Questionnaire

Demographics

1. What is your gender?

   A. Male
   B. Female

2. When you were born?

   A. Before 1980
   B. 1980-today

3. What is your level of Education?

   A. Bachelor degree
   B. Master degree/In Progress Master degree
   C. Doctorate degree

4. What is your experience in Education?

   A. Over 10 years
   B. Over 6 years
   C. Over 2 years

5. How would you rate your computer skills (Not considering game playing skills)?

   A. Proficient (regular user)
   B. Novice (infrequent user)
   C. Non-user

6. Approximately how often do you play video games in a week's time?

   A. 3+ times per week
   B. 1-3 times per week
   C. Not at all

7. On a 1-5 scale how would you characterize your teaching method? Circle a number!

Directed Teacher - Centered				Inquiry/Investigative Student - Centered
1	2	3	4	5

Figure 10.14: Demographic Questionnaire

11

Appendix C Games

In this appendix i will present the EVGs that i came across during this research's framework. I must report that i have played the majority of those games (i.e. the games that were freely distributed or games that i had already played).

PC Games

AquaMOOSE 3D (see figure 11.1) is a graphical environment designed to support the exploration of 3D mathematical concepts where motion can be specified mathematically using parametric equations[23] and in many ways it resembles the logo programming language (Papert 1980) in three dimensions.

The **Zoombinis** (see figure 11.2) is a series of educational computer games. The games feature the adventures of a race of small blue creatures called Zoombinis. In their adventures, they are often required to solve logic puzzles having to do with their individual characteristics or with those of the environment.

In **Restaurant empire** (see figure 11.3) the player controls the kind of cuisine the restaurant serves (American, French, or Italian), what specific food they serve and the staff. The player has to keep guests happy and make money at the same time. In the game, a global culinary conglomerate, Omnifood, controls over 60% of the world's restaurants and is rapidly growing. The player must compete against Omnifood. The player takes the role of Armand LeBeouf, a recent graduate from a French culinary school given the opportunity by his uncle to run his own restaurant. Later, the player is given the opportunity to attract investment capital and open more restaurants.

Geochallenge (see figure 11.4) is a mini game for facebook developed by Playfish. I consists a fun way to learn about world geography and world's landmarks. It works in a competition mode where you can compare your scores to those of your friends and challenge them as an extrinsic motivation. The best part though, is that you can do all those things without having to remember by heart text excerpts from the geography book.

Crayon physics (see figure 11.5) is a puzzle game based on a two-dimensional world simulation were principles of physics (gravity, mass, kinetic energy and transfer of momentum) hold. The game was designed and developed by Petri Purho a 26-year-old from Finland[26, 61].

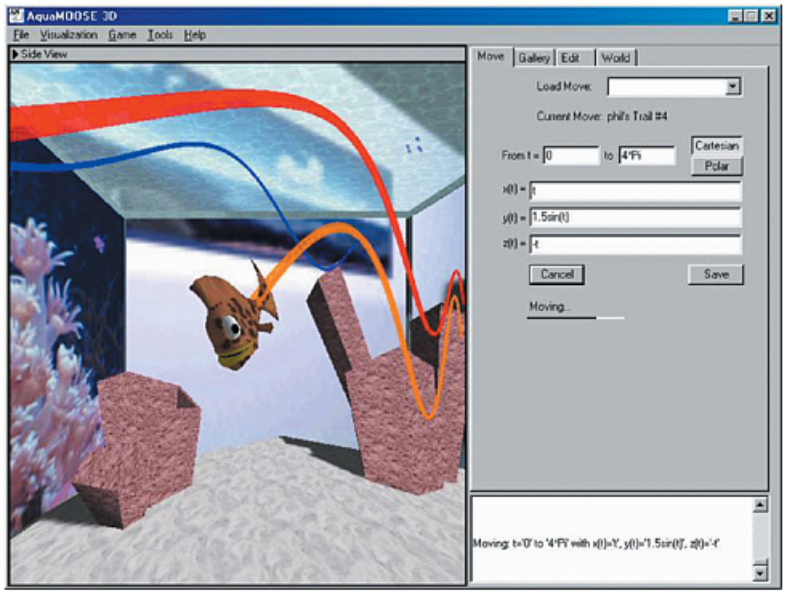


Figure 11.1: AquaMOOS 3D

Secret Door

Pollination

Types of Food

Producing youngs

Figure 11.2: Different Stages of Zoombinis

Figure 11.3: Restaurant Empire

Figure 11.4: GeoChallenge

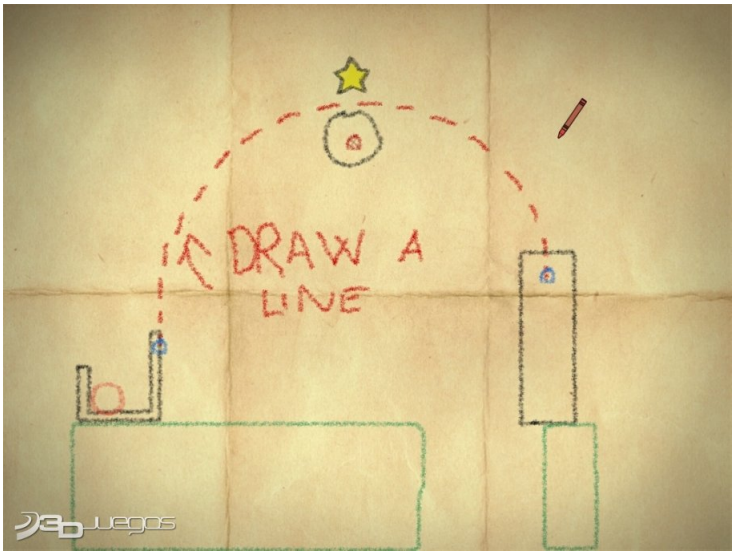


Figure 11.5: Crayon Physics

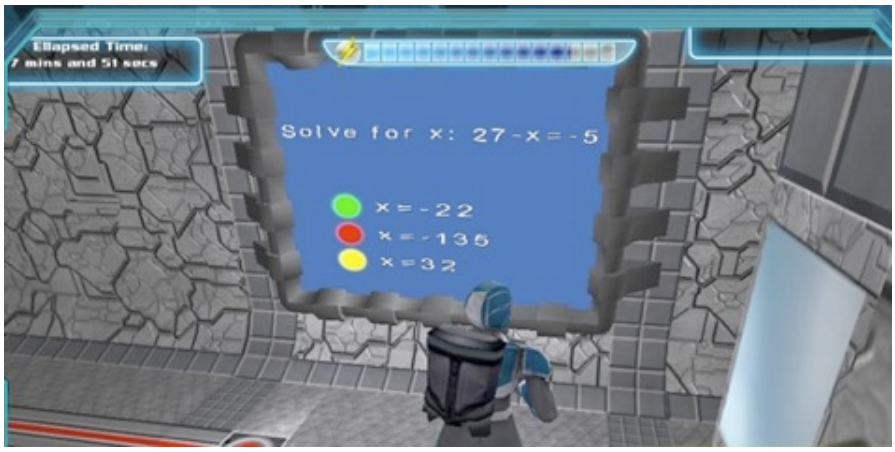


Figure 11.6: DimensionM

DimensionM (see figure 11.6) a role-playing video game that requires quick math skills to keep going. In this game students capture correct answers to questions and get points all while navigating a new planet as space explorers. The game however does not allow for deep knowledge creation and it is not about learning as you play - it is more about drill and practice, since players must already know how to get the answers before they start the game[32].

Ko's Journey (see figure 11.7) is a game for middle schoolers that stands in sharp contrast to drill and practice games. In it, players follow the adventures of a girl who has been separated from her family and must travel across the wilderness. Along the way, she must solve problems using mathematics, including finding the correct proportion of medicinal plants to save a wolf cub and the correct angle to shoot her arrows. Identity and intrinsic mathematics are key components of the game. Moreover, the game tells an absorbing story, which is a key component of game play in order to achieve deeper learning[32].

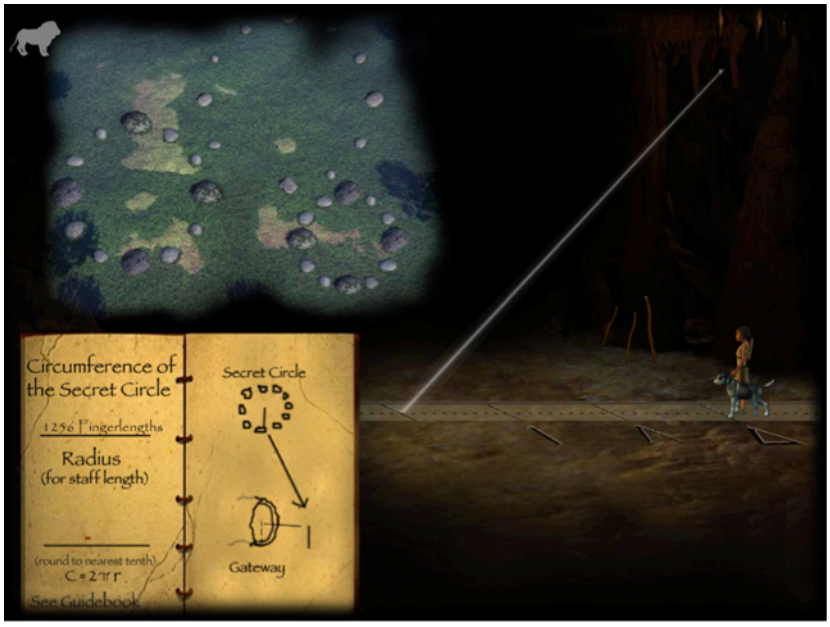


Figure 11.7: Ko's Journey

NIU-Torcs (see figure 11.8) is a rare example of a college-level game that allows for deeper mathematical learning within the game. Brianno Coller and his colleagues developed the game through an NSF grant to help their mechanical engineering students learn numerical methods. Students begin the game by learning how to code acceleration and steering using the programming language C++. Students must calculate numerical roots, solve systems of linear equation and be able to do curve fitting and simple optimization. This game pushes students to start thinking and acting like real engineers[32].

Lemonade Tycoon (see figure 11.9) is a commercial game and it's basic object is to sell lemonade for profit This can be done by adjusting the price, ingredients, customer wait times, the weather and many more factors. This game can be used by a calculus professor as an introduction to optimization thus engaging the students[32].

Civilization III (see figure 11.10), like the other Civilization games, is based around building an empire from the ground up, beginning in 4,000 BC and continuing slightly beyond the modern day. The player must construct and improve cities, train military and non-military units, improve terrain, research technologies, build Wonders of the World, make war or peace with neighboring civilizations, and so on. The player have to balance a good infrastructure, resources, diplomatic and trading skills, technological advancement, city and empire management, culture and military power to succeed[61]. Squire, as a former Montessori teacher, reports that he can easily imagine students using Civilization III to investigate historical questions within a system which is organized around students pursuing questions of intellectual interest[56].

BioHazard provides a medical emergency simulated situation where players assume the role of medical practitioners who respond to an epidemic infectious disease. The players learn about human body, medical instruments, emergency situation control and effective resource management. Resources are provided by non-player characters. The players should allocate the resources efficiently and respond to new situations arise dur-

Figure 11.8: NIU-Torcs

Figure 11.9: Lemonade Tycoon

Figure 11.10: Civilization III

ing the game. The players can win the game if they identify the disease, prevent further infections, and cure those already infected[42].

La Jungla de Optica (see figure 11.11) provides a simulated adventurous environment where the players learn about basic concepts of optical physics. They apply their knowledge to solve problems arise in the game missions. The players are dropped in the fabled Jungle of Optics and should help the two main characters of the game escape from the treasure of thieves and return home. To accomplish this mission, the players use their knowledge to solve optics puzzles and complex open-ended problems. They also construct optical artifacts such as telescopes and camera and receive real time feedback and detailed analysis of their game progresses[42].

Daelalus' End provides a simulated virtual world where the players assume the role of civil engineers and learn about conducting civil engineering projects such as constructing dams or highways. In addition, the players learn about the effects of constructing these civil projects on the global environment. Daelalus' End is a multiplayer game where the players interact with each other to manage the project decision making stages and to address controversial issues related to the projects and their environmental effects. The players have to use the limited money and time efficiently in order to accomplish the missions[42].

Quest Atlantis (see figure 11.12) developed by Indiana University, is a multi-user 3-D virtual environment that immerses children, ages 912 in educational tasks including language arts, mathematics and social studies. It has been designed based on the combination of experiential and inquiry-based learning theories. The goal of Quest Atlantis is to establish educational worlds where children can become empowered scientists, doc-

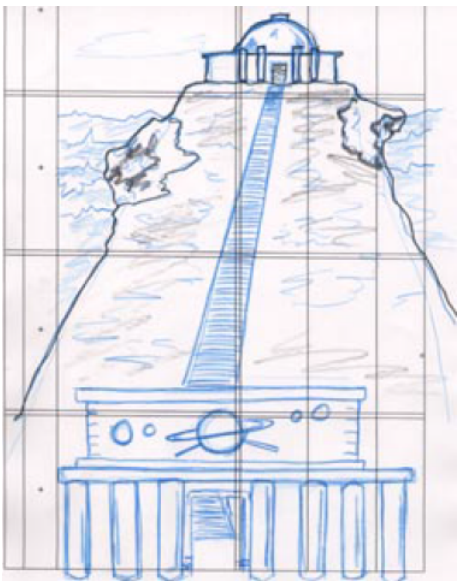


Figure 11.11: La Jungla de Optica

tors, reporters and mathematicians who have to understand their disciplinary content to accomplish desired ends[42, 61].

SimSchool (see figure 11.13) is a classroom simulation that supports the rapid accumulation of a teacher's experience in analyzing student differences, adapting instruction to individual learner needs, gathering data about the impacts of instruction and seeing the results of their teaching.In other words it is like a "flight simulator" for educators - a place where instructors can explore instructional strategies, examine classroom management techniques and practice building relationships with students that will translate into increased learning[3].

Logo (1967) (see figure 11.14) is a sophisticated programming environment where students could be move and altered a turtle-shaped icon. Through inputting commands, essentially very basic programming codes, they could use the turtle to draw geometric shapes, from circles to stars to spirals. While Logo's use peaked during the mid-1980s, it was nonetheless pivotal in the development of educational programs, teaching a generation of kids that programming wasn't only accessible, it could also be fun.

In **Lemonade Stand** (1979) (see figure 11.15) the players run a lemonade stand, choosing the amount of ingredients to buy, how to advertise and what to price lemonade. All of these choices, as well as uncontrollable factors like weather, play into how much profit the lemonade stand turns. Lemonade Stand, and others early economics-based games like M.U.L.E., would inspire a large number of future games including Lemonade Empire, Lemonade Tycoon, Hot Dog Stand and so on and so forth.

In **Snooper Troops** (1982) (see figure 11.16) players comb the streets looking for clues, question witnesses, investigate homes while occupants are away and use the Snoop-Net computers to solve crimes. The game is fun, interesting and boosts problem solving and creative thinking skills while teaching kids how to take notes, organize information, and expand their knowledge about police work.

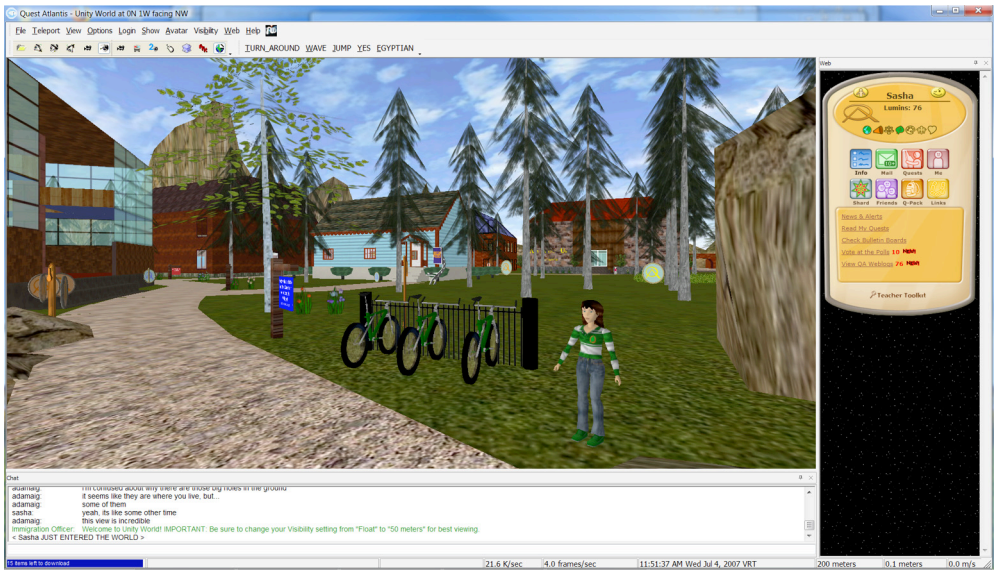


Figure 11.12: Quest Atlantis

Figure 11.13: SimSchool

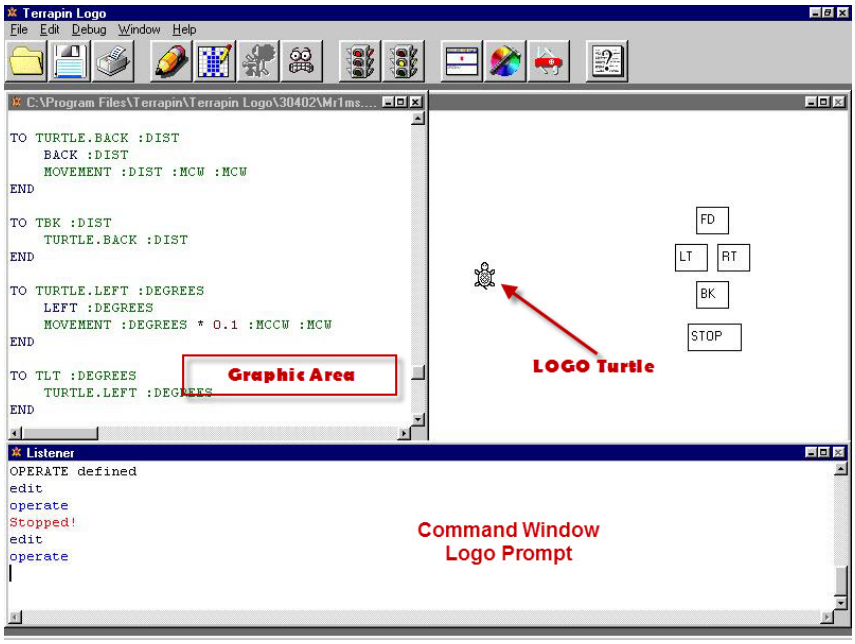


Figure 11.14: Logo

Figure 11.15: Lemon Stand

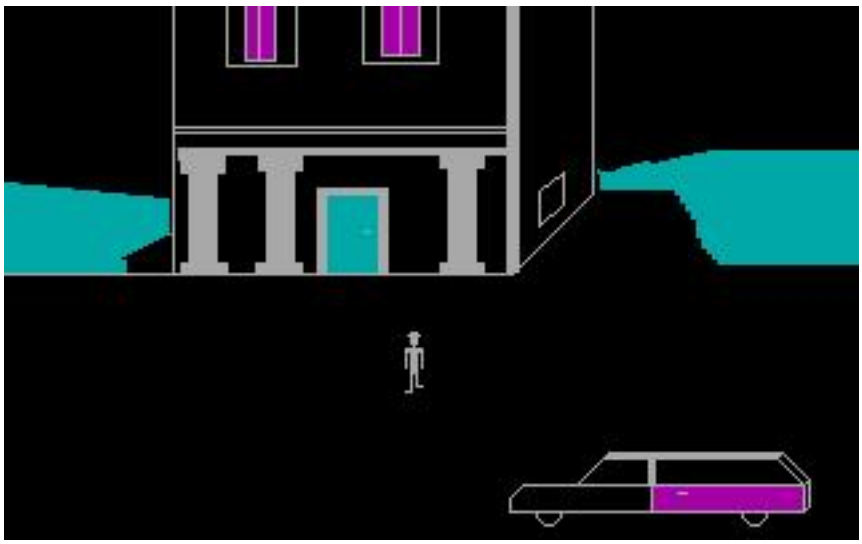


Figure 11.16: Snooper Trooper

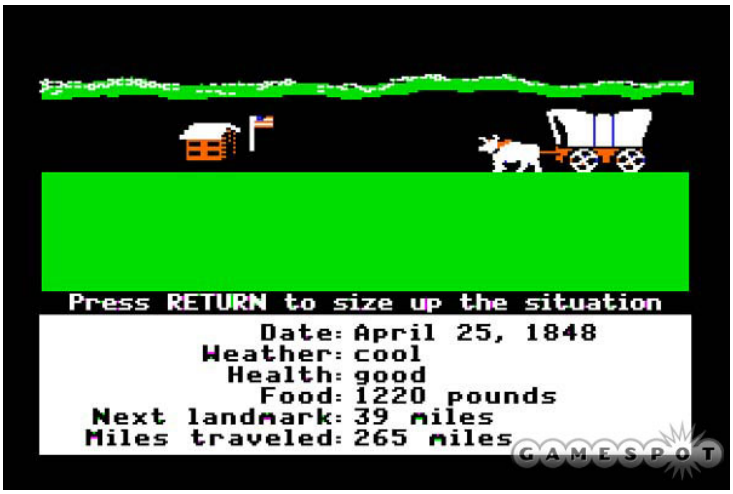


Figure 11.17: Oregon Trail

In **Oregon Trail** (1985) (see figure 11.17) gameplay is fairly simple, asking players to successfully lead a family of settlers along the Oregon Trail, battling swollen rivers, broken axles, and the dreaded dysentery along the way. The early graphics were pretty rudimentary, but the game was among the first to show just how engaging a game with an educational context could be.

In **Where in the World Is Carmen Sandiego?** (1985) (see figure 11.18) gameplay involves chasing down a master thief/spy, the eponymous Carmen Sandiego, around the world and answering geography questions correctly in order to retrieve objects and foil her plans.

Odell Lake (1986) (see figure 11.19) was an early simulation game that challenged players to take on the identity of one of six species of fish living in Odell Lake, a real lake in Oregon. The object? Keep your fish alive by avoiding predators, eating food, and exploring the lake. Smart choices would earn you points, poor ones would take them away

Figure 11.18: Carmen Sandiago

Figure 11.19: Odell Lake

or end the game. Teaching kids about ecosystems and wildlife, Odell Lake was one of the first science-focused educational games on the market.

Reader Rabbit (1986) (see figure 11.20) teaches students how to read and spell through simple but fun mini-games. The first game in the series taught language arts, featuring a variety of simple games designed to teach schoolchildren basic reading and spelling skills. Originally, the title character's name was changed to reflect a change in subject, as with Math Rabbit, but it has apparently since been decided to retain the character's original name regardless of the subject area covered by a particular game[61].

In **Number Munchers** (1987) (see figure 11.21) students must "munch" all of the numbers that fit into a specific category. A correct answer yields a fun cut-screen. An incorrect one means getting eaten by a monster (called Troggles in the game). Number Munchers was among the first to transform basic math problem solving into something students actually look forward to doing, a hallmark of many educational games today.

LOOM (1990) (see figure 11.22) was one of the earliest games released by LucasFilm Games (now known as LucasArts) and wasn't necessarily intended to be an educational game. Yet the problem solving and musical memorization skills used to navigate the

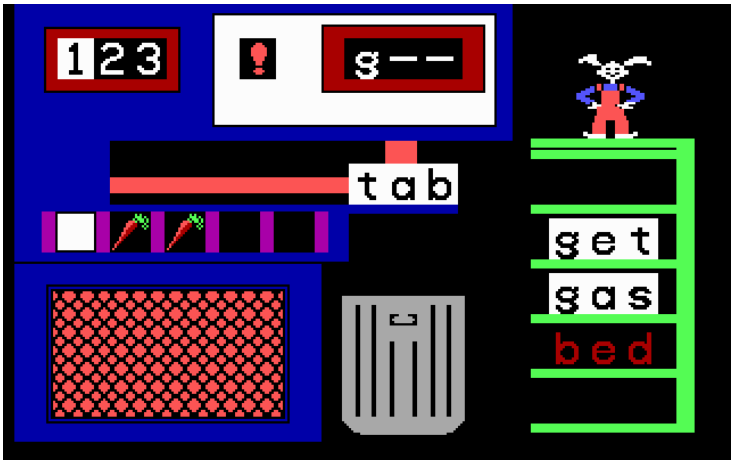


Figure 11.20: Reader Rabbit

Figure 11.21: Number Munchers

game's protagonist through the fantasy world he inhabits certainly didn't hurt developing minds to exercise. The game also boasts a rich, young adult literature-worthy plot, including a 30 minute audio drama that draws on Greek mythology to set up the game. LOOM and the many high-quality adventure games from LucasArts that would follow would set the bar for puzzle games, many of which still challenge young gamers today.

Lemmings (1991) (see figure 11.23) wasn't really intended to be educational but is actually a great tool for teaching kids about planning, problem solving and creative thinking. To advance, players must successfully guide a group of lemmings through a danger-filled setting using selected skills that alter the landscape.

Math-City consists of a virtual environment where students can build and maintain a city with residential, commercial and industrial buildings as well as renewable and non power sources. The student has the role of "City Developer" or Mayor if you will. The main goal of the game is to create a city that maximizes the happiness of its residents. The game includes five happiness factors: Pollution, Police, Fire, Health and Big Buildings. If students do not have sufficient money to continue building they can earn additional funds by answering mathematics questions. These questions consist of word problems and fraction exercises. The word problems are designed to test students' understanding of the four arithmetics operations in a problem-solving context. The game is similar in the basic idea with the commercial video game Simcity of Will Right.

MathQuest, is a an online role playing game (RPG) developed to teach primary

Figure 11.22: Loom

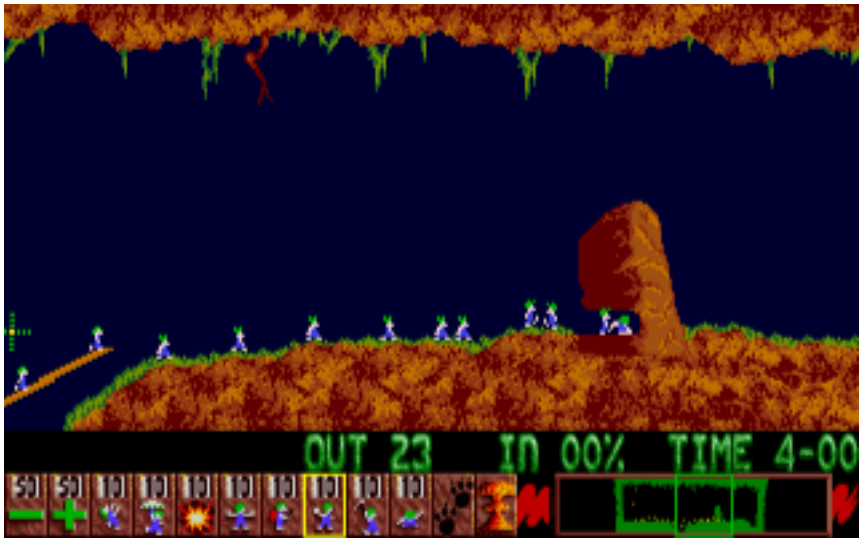


Figure 11.23: Lemmings

Figure 11.24: Kodu

Figure 11.25: Calculation Nation

school children about numbers and basic mathematics operations. The student assumes an apprentice role helping the villagers of this virtual world with their problems. The game consist of a virtual world with which the player can interact and of a number of mini-games in which the learning procedure is taking place.

Kodu (see figure 11.24) is a visual programming language made specifically for creating games. It is designed to be accessible for children. The programming environment runs on the Xbox, allowing rapid design iteration using only a game controller for input. The core of the Kodu project is the programming user interface. The language is simple and entirely icon-based. The Kodu language is designed specifically for game development and provides specialized primitives derived from gaming scenarios. Programs are expressed in physical terms, using concepts like vision, hearing, and time to control character behavior. While not as general-purpose as classical programming languages, Kodu can express advanced game design concepts in a simple, direct, and intuitive manner[1].

Calculation Nation (see figure 11.25) is a game formed by the NCTM Illuminations project and consists of a number of mini games for high school mathematics divided by subject in two categories: algebra and geometry[31].

Timez Attack (see figure 11.26) is a commercial game designed from Big Brainz Inc. and concentrates in teaching the player the multiplication tables[39].

Figure 11.26: Timez Attack

Figure 11.27: Portal

Portal (see figure 11.27) is a popular sci-fi video game. The player assumes the role of a young woman trapped within a Science complex. He is forced to solve tests of varying difficulty in chambers designed by an AI-gone-rogue. During the early stages of the game, the player is granted access to the Portal Gun, a piece of equipment that allows the player to create portals that are large enough for her to travel through. These portals act as gates between each other, allowing the player to quickly traverse areas or reach normally unreachable places. In this game the player is challenged to analyze the constraints of the area around and solve spatial puzzles. This experience leverages the player's understanding of physics and 3D geometry[28].

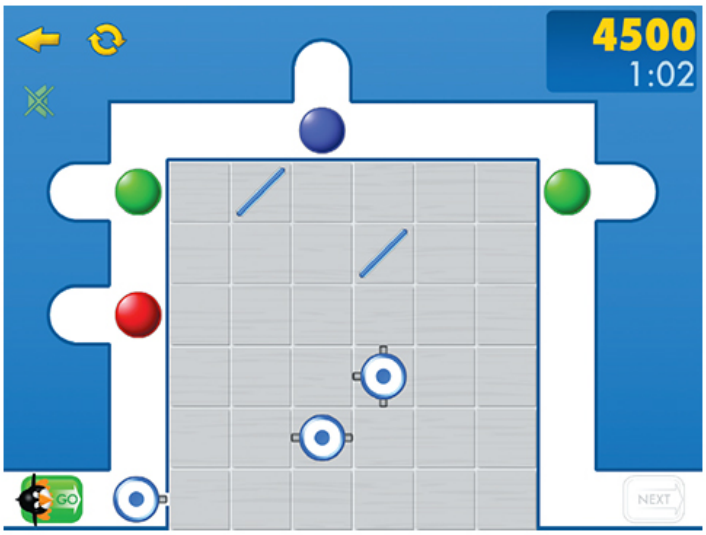


Figure 11.28: KickBox

Apps

KickBox (see figure 11.28) uses a penguin character called JiJi that players must help get from one end of the corridor to the other. Players position beam-splitters and reflectors to direct lasers that knock out obstacles in JiJi's path. Solving such a puzzle provides excellent practice in mathematical thinking, completely separate from the more familiar formulas, equations and dreaded "word problems"[16].

Wuzzit Trouble (see figure 11.29), the cute and fuzzy creatures must be freed from traps controlled by gearlike combination locks. Players collect keys to open the locks by solving puzzles of varying difficulty[16]

MotionMath (see figure 11.30) is a Tetris-inspired game that uses the motion sensors in a smartphone or tablet to allow players to tilt the screen to direct descending fractions to land on the right location on the number line. This game is an excellent introduction to fractions for younger children, as it connects the abstract concept to tactile, bodily activity[16].

In the math puzzle game **Refraction** (see figure 11.31), players learn about fractions and algebra. In this puzzle, the player has to split a laser beam a sufficient number of times to power all of the alien spaceships on the screen. The game is also designed to be modified on the fly, in an effort to capture data about what teaching methods and reward systems work best for students[16].

DragonBox (see figure 11.32) challenges players to isolate the glittering box (containing a growling dragon) on one side of the screen. What they are doing is solving for the x in an algebraic equation. But there isn't an x to be seen in the early stages of the game. As the player progresses through the game, mathematical symbols start to appear, first as names for the objects, later replacing the object altogether. This game demonstrates very clearly that solving an algebraic equation is not fundamentally about manipulating abstract symbols, but is reasoning about things in the world, for which the

Figure 11.29: Wuzzit

Figure 11.30: Motionmath

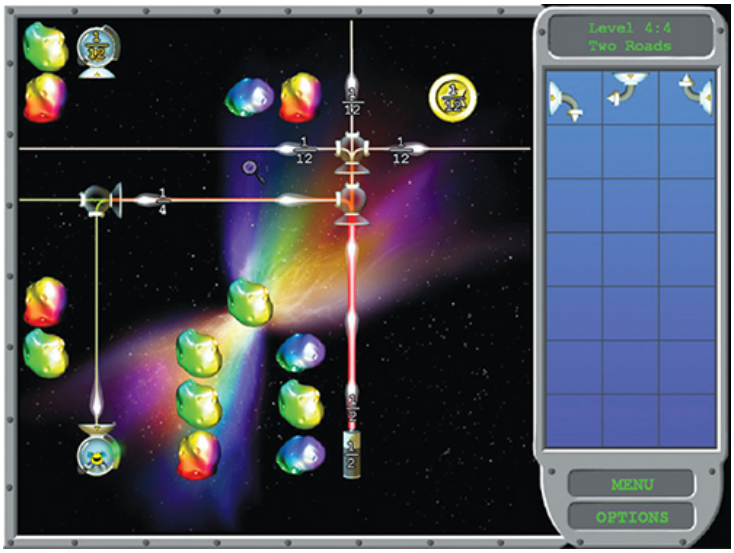


Figure 11.31: Refraction

Figure 11.32: Dragonbox

symbols are just names. DragonBox provides a more user-friendly interface to algebraic equations - but it's still algebra, and even young children can do it[16].

2048 (see figure 11.33) is played on a simple gray $4x4$ grid, with numbered tiles that slide when the player moves them using the four arrow keys. Every turn, a new tile will randomly appear in an empty spot on the board with a value of either 2 or 4. Tiles slide as far as possible in the chosen direction until they are stopped by either another tile or the edge of the grid. If two tiles of the same number collide while moving, they will merge into a tile with the total value of the two tiles that collided. The resulting tile cannot merge with another tile again in the same move. The game is won when a tile with a value of 2048 appears on the board, hence the name of the game. After reaching the target score, players can continue in a sandbox mode that continues beyond 2048. This game cannot be categorized officially as educational though in a way it is about calculations (doubling numbers) and strategic reasoning in order to make "good" moves in the $4x4$ grid.

Figure 11.33: 2048

12

Appendix D Participants Screenshots

In this Appendix i juxtapose the final screenshots of the participants gaming sessions which show the strategy and gameplay character of each player.

Figure 12.1: Participant No1

Figure 12.2: Participant No2

Figure 12.3: Participant No3

Figure 12.4: Participant No4

Figure 12.5: Participant No5

Figure 12.6: Participant No6

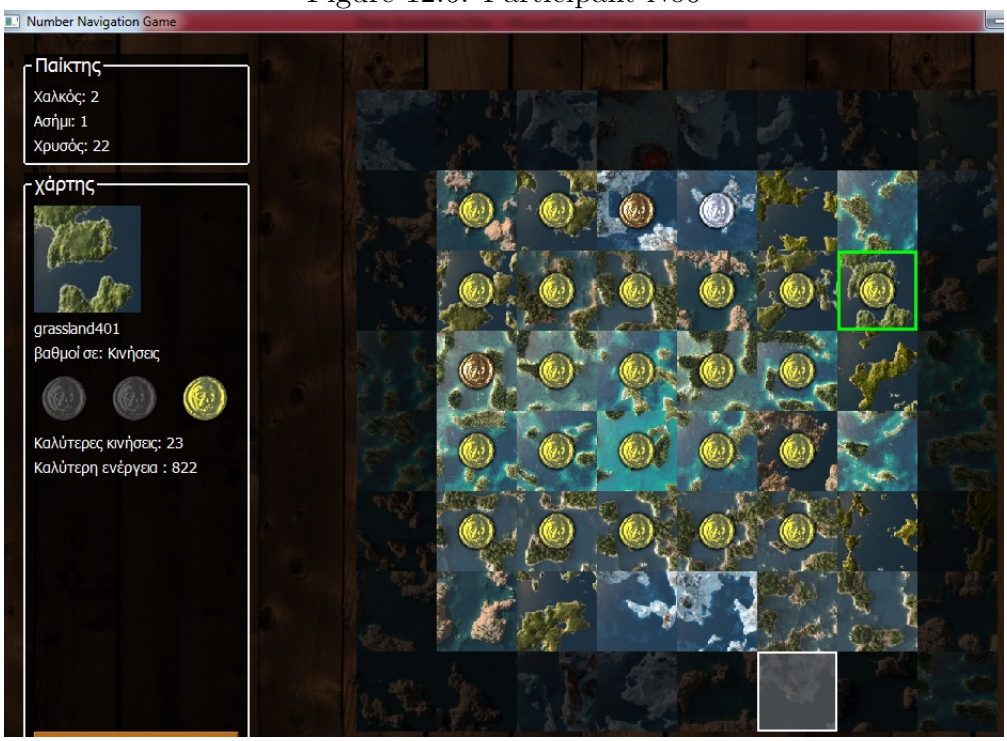


Figure 12.7: Participant No7

Figure 12.8: Participant No8

Figure 12.9: Participant No9

Figure 12.10: Participant No10

Figure 12.11: Participant No11

Figure 12.12: Participant No12

Figure 12.13: Participant No13

Figure 12.14: Participant No14

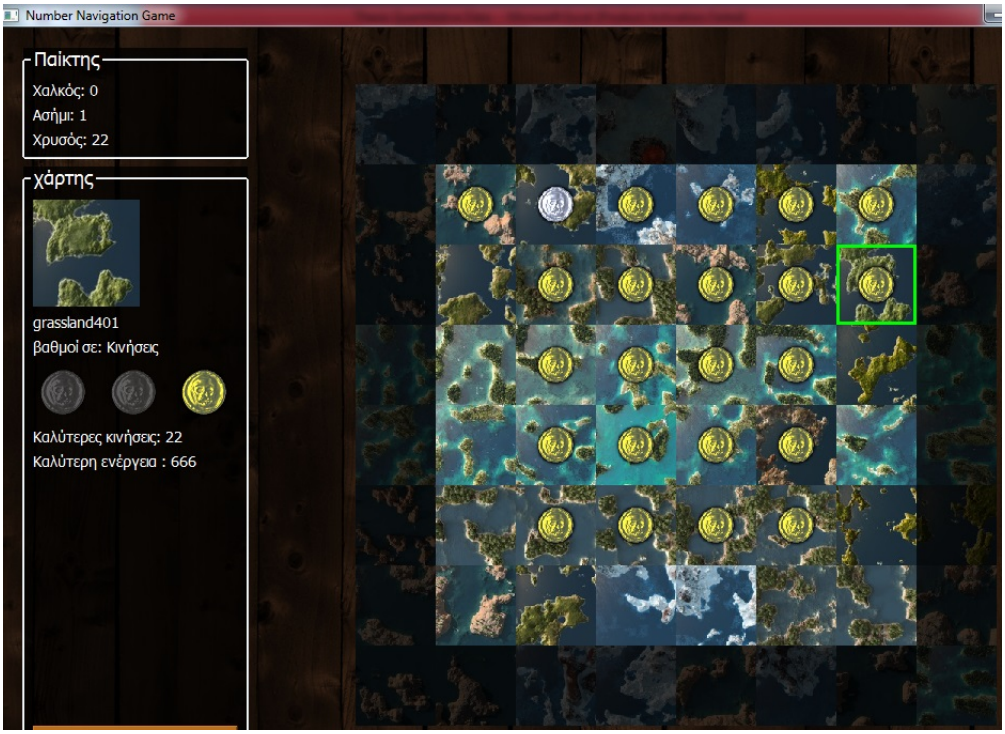


Figure 12.15: Participant No15

Figure 12.16: Participant No16

Figure 12.17: Pilot Participant

General Informations For This Study

This thesis has been written using the LaTeX.
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