Research on the impact of using interactive game based learning to teach mathematics

Masters Thesis in
Information and Communication Technology

Agder University College
Faculty of Engineering and Science

Grimstad, 2005

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http://student.grm.hia.no/master/ikt05/ikt590/g20
http://fag.grm.hia.no/ikt590/hovedoppgave/

Abstract

The number of students who study scientific subjects has continued to drop over a long period of time. Compared to 2004, there is a 12% decrease in High School students who study mathematics and a 5% decrease in applicants for technology studies at College and University level in 2005 [1]. These numbers concern employees of the technology sector as they have predicted a large need for mathematicians in the future [19].

The educational system is under constant change to take advantage of new educational methods that modern technology allows for. The Heriot Watt University in Scotland showed that the interest around mathematics boosted after they launched their interactive solution Schoolar. Personal Computers are common property today and most schools have computer labs with Internet connection. This assumption allows us to focus on how computers may be used to improve the teaching by securing quality and by appealing more to the youth than traditional classroom education.

Today there exist few computer games that are designed to help and motivate high school students in the field of mathematics. The computer game industry is a multi billion dollar industry that knows what the different target groups are buying. The art of teaching and learning is a well researched area. But few have examined the effects that may arise when combining the above into educational computer games.

We have performed surveys on the target group and created a playable educational computer game to find what impact computer game based learning have on the students.

Preface

This is a master thesis in Information and Communication Technology at Agder University College. The thesis is carried out in one semester and is worth 30 credit points.

This thesis was initiated by assistant professor Ola Torkildsen Aas, pedagogic director and writer for parAbel. parAbel is a project that aims to increase the interest of mathematics among high school students by using modern techniques such as the internet and multimedia.

Our supervisor, Ola T. Aas, has been a great resource to us. He was the one who introduced us to the assignment. His inspiration and motivation has had a positive effect on us, and was important for our decision to undertake this assignment. Ola T. Aas has provided us with valuable feedback at the commencement and completion of all project phases.

We would like to express our gratitude to the 2MX-classes at Dahlske High School and their teachers Øystein Haga and Trond Nilsen for their participation in our surveys and in testing the game prototype.

We would also like to thank the following persons for their efforts in providing us with information and views that has helped us in our research: Bjørn Schinnes (parAbel), Cornelia Brodal (pHD HiA) and Per Egil Pedersen (Professor, research expert, HiA).

A CD containing a playable prototype, complete code documentation and this report is provided with the deliverance.

Daniel Fløtre Erling. G. Kristiansen Jan Heggernes

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1 Introduction

Learning curriculum and methodologies of modern day societies are constantly evolving, to keep up with the ways in which students are studying and behaving in general and to utilize new technologies. There is less focus on traditional methods of learning and teaching and more of a shift towards alternative methods of education which take advantage of advancements in technology, such as computer based learning and other forms of interactive multimedia.

As students are adapting to these new ways of learning, they begin to lose interest in courses which require hard work in the traditional classroom education style. Studies show that the interest and awareness around nature and science is larger then ever, yet the classical subjects of math, physics, chemistry and biology are dropping severely in attendance rates [3]. Therefore, it would be of great benefit to the students and schools if the pedagogic approach is reviewed with interactive learning methods that motivate the students back to this field. This would provide an enhanced and enjoyable learning experience to the student and hopefully help to motivate them for further work in the given field.

Agder College University (HiA) has an education research environment that is active in finding solutions for electronic learning. parAbel is a national project initiated by HiA that focuses on meeting students at their own arena by offering a web based educational solution for mathematics. Ola T. Aas, pedagogic director at parAbel, is the initiator of the thesis, looking for creative input and research in the area of creating successful games with a correct educational approach.

1.1 Thesis description

We would perform an initial survey of our target audience, measuring variables such as their average time spent using computers, general mathematics aptitude, and other factors which will impact our study. Based on these initial results, we will develop a

prototype game that incorporates certain pedagogic principles and didactic methods. As the game is tested on students at the local high school we will collect the results from each player. Also we will use a reference group of students on which we will conduct a test devised by us in parallel with the test group. Based on all the results collected from all the stages of the research we will determine the effects and usability of game based learning. Specifically what can and should be done differently and what works for learning mathematics by interactive computer games.
(Ola T. Aas, Daniel Fløtre, Jan Heggernes, Erling G. Kristiansen)

1.2 Purpose

The purpose of this project is to survey the impact of game based learning by utilizing personal computers and information technology. With this thesis we wish to establish a research platform that relieves applicable methods and to map out the direction for further development of computer game based education.

Game based learning has the potential to engage the students in a more active way than traditional learning, by having a more attractive appearance and by requiring everyone to participate. Through a graphical interface, computer games may help the students connect mathematical theory with real life objects. Computer games may give the teachers accurate feedback for every student, and provide information that can be used to improve the teaching.

This project includes a playable prototype that put some of our ideas to life. A prototype like this is easily tested on the target group where instant reactions and constructive feedback in form of interviews or questionnaires adds a great value to the work.

The vision behind the prototype is to create a fantasy or virtual world where the students create their own character. The characters play the role of personalizing the students with the game and to keep track of progress. The students will always continue at the point where they left the game, increasing playability. Furthermore, the virtual world may

contain a number of independent game modules, offering expandability and changeability. Each module may offer different approaches to active learning.

1.3 Statement

We believe that by combining the recreational aspects of an interactive computer based experience with traditional course material we can offer an enjoyable learning experience to students, without lowering the educational quality.

In this project we will try to derive which factors need to be considered while developing educational software in the form of a computer game, followed by developing a prototype of how such an application would work.

After the development, we will have the software tested by relevant students and gather feedback in forms of user polls, teacher comments and statistics from the software to determine how well the prototype succeeded in actually teaching students the intended material. We will also determine the perceived entertainment value and whether or not the test subjects preferred the gaming experience over conventional teaching methods.

1.4 Hypotheses

Game based learning provides an enhanced and enjoyable learning experience compared to conventional methods of teaching.

Interactions and use of computers increase the students' motivation to work with school material.

Interactive graphical representation of mathematical problems may enhance the understanding of the subject by response and discoveries.

Game based learning will give an equal or higher level of educational quality than the conventional methods.

Game based learning enables more comprehensive tracking of progress than conventional education in a classroom and an efficient way to generate detailed statistics for individuals as well as groups.

1.5 Limitations

The project is limited to be dealing with one mathematical problem from the 2MX curriculum, specifically chapter 9 in the Sinus textbook [2] considering combinations and probability.

The number of student test groups is limited two classes studying 2MX. These are two parallel school classes from the same school, Dahlske High School/Junior College. One class is to play our prototype for approximately one hour, the other class will work as a reference class. The students are about 17 years old, aged and experienced enough in the relevant field to give valuable feedback. Due to severe limitations considering the time scope of this thesis, these results will not be conclusive. What we hope to gain is an indication of what degree our visions and ideas appeal to the target group and to set the course for further development.

Due to the fact that this is research related to a software development project, and there are non graphics artists in the project group, the game features concepts that require little or non media effects such as arts and audio.

1.6 Existing projects

There has not been performed much research in providing the target group, 16-18 year old high school students, with educational computer games. Educational games for children have existed for decades, while educational software for teens and adults is

pretty much limited to online lecture notes. We assume this is tied up in economy and commercial potential: Parents are likely to buy their 6 year old an educational game, but would they buy their 17 year old this kind of software? Many 17 year olds are also to some degree responsible for their own personal economy and we assume educational software at least must compete with commercial 100-million dollar games to become attractive to this target group. Education is free in Norway, and students may not be prepared to spend money on school related material. This is why governmental organizations must be the driving force in developing such solutions.

1.6.1 parAbel

parAbel is a Norwegian national project that responds to the declining numbers of students who scientific subject such as mathematics. A goal set by the Norwegian government is that 40% of all high school students are to choose scientific subjects as their primary focus within 2007. (*Utdannings- og Forskingsdepartementets strategiplan for styrking av realfagene 2002-2007*). Studies show that the interest among the target group for technology is greater than ever. Science television shows such as „*Newton*“ and „*Schrødingers katt*“ are increasingly popular, and most teens use computers every day. The intention of parAbel is to meet the target group at their own area by using internet and multimedia technology. parAbel provides a web based solution where the students may read and do interactive exercises. [3]

1.6.2 Scholar

Scholar was initiated by the Heriot Watt University in Scotland. parAbel is in many ways inspired by Scholar, but uses a newer and better development platform that provides more multimedia options. Heriot Watt University experienced the same decrease in students who were applying technical courses, and wanted to take advantage of information technology to reach out to the students. The response for this project was formidable, after only two years the numbers of students who took science in high school was increased by 17% and the number of students who applied to Heriot Watt faculty of technology increased by 10%. [4]

1.6.3 The education arcade

Massachusetts Institute of Technology commenced in 2001 a large scale research to gather evidence that high quality educational games could be made or could be effectively used in the classroom. Through the Games-to-Teach Project, a Microsoft iCampus initiative with the Comparative Media Studies department at the Massachusetts Institute of Technology, MIT began to explore key issues in the use of a wide variety of media in teaching and learning. Based on survey work, they developed a suite of conceptual frameworks to support learning across math, science, engineering, and humanities curricula. Working with top game designers from industry and with faculty across MIT's five schools, 15 game concepts were conceived that support pedagogy for how advanced math and science content could be blended with game play in unique ways, as well as models for supporting humanities education. Given the large matrix of creative and teaching possibilities that were identified, they developed a subset of prototypes to implement as proofs-of-concept, including games to support teaching in physics and environmental engineering. [5]

1.6.4 The Math Forum

The Math Forum is a leading center for mathematics and mathematics education on the Internet. Operating under Drexel's School of Education, Math Forum’s mission is to provide resources, materials, activities, person-to-person interactions, and educational products and services that enrich and support teaching and learning in an increasingly technological world. The Math Forum online community includes teachers, students, researchers, parents, educators, and citizens at all levels that have an interest in math and math education.

The Math Forum does not develop a particular solution or product, but offers a number of interesting articles discussing almost any applicable topic related to math teaching. [6]

1.7 Research motivation

Because of the time scope available for completing this thesis, we have limited this project to deal with one subject from the 2MX curriculum. We wanted place our research work in an unexplored field, so that our findings may be valuable to others that work with educational games. parAbel is situated at HiA Grimstad and it was natural for us to establish contact with Bjørn Schinnes to learn about parAbel and see how we could avoid overlap of our work. We also contacted Øystein Haga at Dahlske high school / junior college to get his view on what part of the curriculum such a game prototype should cover to provide the most help to his students. Considering the answer we got we chose to select the "combinations and probabilities" as covered by chapter 9 in the Sinus textbook. We have also performed a questionnaire within the target group of students to survey their habits and interests within the use of information technology, computer game interests and math skills. This questionnaire is described in detail later.

2 Literature review

2.1 Educational Methods

The human mind has been extensively studied with the purpose of finding the keys to successful learning. Learning has been defined as a permanent change in behavior which in turn allows us to think of education as the experience provided that causes the change in behavior.

Definition of learning:
"Learning is a relatively permanent change in behavior or behavior potentiality that results from experience and cannot be attributed to temporary body states such as those induced by illness, fatigue or drugs" (Hergenbahn and Olson, 2001)

This leads to developing techniques that have proven effect on human behavior. Two prominent and yet very distinctive directions within learning techniques are the reaction based behaviorism and a cognitive psychological approach.

2.1.1 Behaviorism

Learning was manifested by a change in behavior (Hergenbahn and Olson, 2001), with an emphasis on a connection between a stimulus and a response. From a behaviorist perspective, the goal of education is to 'ensure survival of human species, societies and individuals' (Merriam and Caffarella, 1999). The main principles of behaviorism weight the importance of feedback, skills development and training, computerized and programmed instruction, competency-based education, and constructive pre-alignment of content, teaching methods and assessment.

Behaviorists focus on observable behaviors, rather than internal thoughts such as intentions and wishes (constructivism). In more detail they look for what triggers behavioral changes and behavioral consequences. Thorndike's (1932) Law of Effect says

that you learn something about your behavior because of the consequences that it has for you.

The classical example below shows the importance of giving the correct feedback at the correct time. Instead of giving the child attention when well conducting, the teacher gives attention to the children that are disrupting the class.

"A child is in a school classroom. When he is quiet (reading or drawing) the teacher pays no attention to him. He throws a ball of paper at another child. The teacher tells him off. He starts reading but after a while throws something again. The teacher pays attention to him. After a while he frequently throws things." (Greene and Hicks, 1984)

More specifically reinforcement is defined as anything which increases the probability of a response or particular behavior; positive reinforcement occurs when something rewarding happens after the behavior, whilst negative reinforcement occurs if something unpleasant is removed after the behavior. (See table 1)

Consequence	**Effect on behavior**
Positive reinforcement	Increase
Negative reinforcement	Increase
Punishment – produce something unpleasant	Decrease
Punishment – remove something pleasant	Decrease

Table 1: Behavioristic reinforcements. (Greene and Hicks, 1984)

Behaviorism was the leading teaching technique used at educational facilities all over the world until the late 20th century. It is still recognized as an effective method in teaching small children social skills and in animal training, and the fact that reinforcement increases the effect on behavior is timeless. [7]

2.1.2 Cognitive psychology

Cognition is defined by Webster's Dictionary as "the act or process of knowing in the broadest sense; specifically, an intellectual process by which knowledge is gained from perception or ideas".

Cognitive psychology emphasizes, in contrast to behaviorism, on unobservable constructs such as mind, memory, attitudes, motivation, thinking, reflection, and similar presumed internal processes (Alessi & Trollip, 2001). These internal processes enable us to gain knowledge through understanding of concepts and theories in different subject matter domains and general cognitive abilities, such as reasoning, planning, problem solving, and comprehending language (Greeno, Collins & Resnick, 1996). [6]

With a general idea of how the human mind works, teaching may be seen as creating an environment that utilizes these abilities.

2.1.2.1 The human brain

Knowing how the human mind works is essential in order to understand how we learn. The human brain weight approximately 1.5kg and consists of more than 100 billion neurons. Each neuron may have between 5.000 to 50.000 connections to other neurons, building structures that allow storage of tremendous amounts of information and knowledge. It is believed that the neurons build connections through study and elaborations throughout the lifetime of a human being.

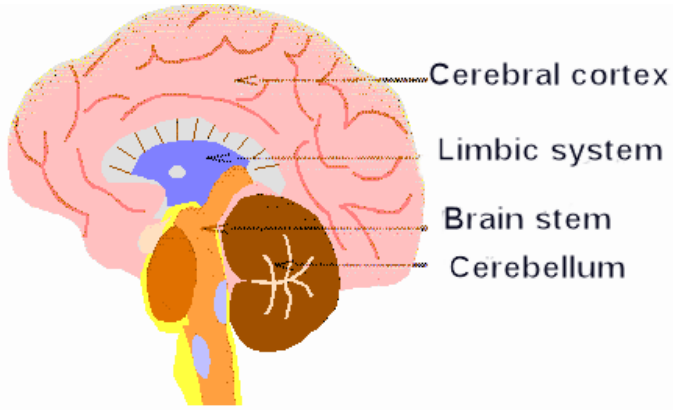


Figure 1: Overview of the human brain

The picture above shows four basic structures in the brain which are important for bodily functions and for learning and memory. The brain stem is concerned with survival functions and regulation of the body system. The cerebellum controls automatic movement patterns such as walking, running and biking. The limbic system processes short term memory into long term memory as well as emotions. The cerebral cortex is the area of the brain where sensory data is received and analyzed, decisions are made and behavioral responses are activated. [8]

2.1.2.2 The stage theory

The stage theory focuses on how information is stored in the memory of the human mind. Atkinson and Shriffin (1968) propose that information is processed and stored at three stages: [9]

- Sensory memory – seconds
- Short term memory – days
- Long term memory – years or lifetime

Storing information in the long term memory requires three separate stages or processes:

- Attention – process to short term memory.
- Repetition – maintain in short term memory
- Elaboration – process to long term memory.

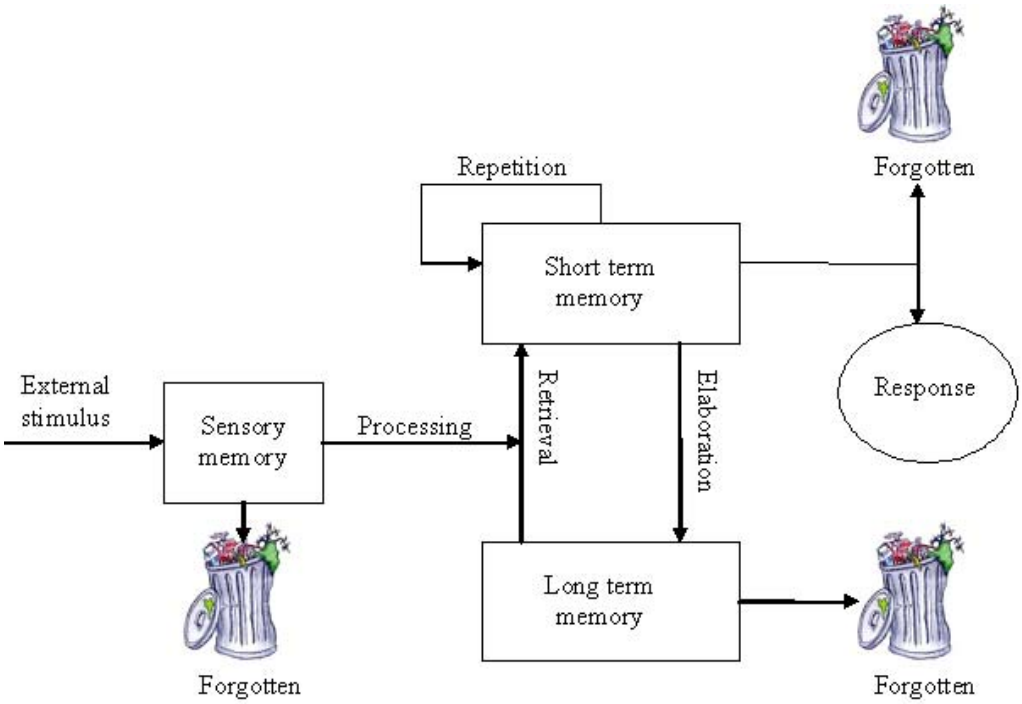


Figure 2: The stage theory

2.1.2.3 Blooms taxonomy

Blooms taxonomy (Benjamin Bloom, 1954) divided the cognitive domain into six levels: knowledge, comprehension, application, analysis, synthesis and evaluation.

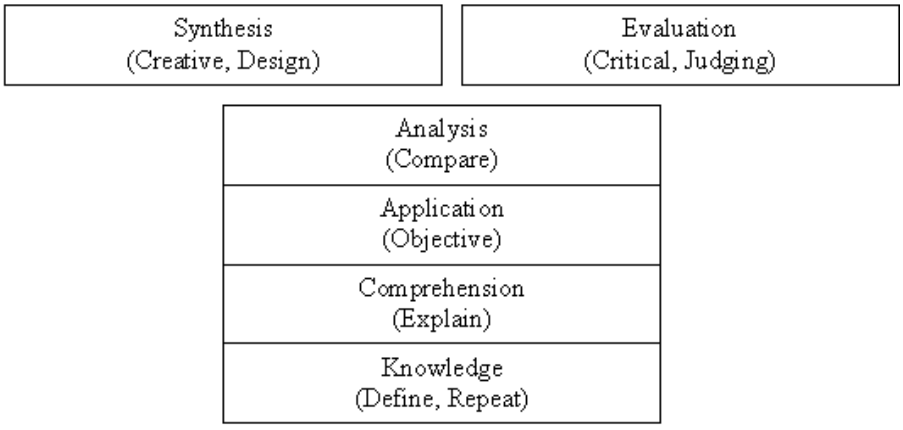


Figure 3: Bloom's taxonomy

The taxonomy provides a useful structure in which to categorize test questions, since educators will characteristically ask questions within particular levels. This figure is also visualized as a pyramid with knowledge at the bottom and synthesis and evaluation at the

top. The width of the pyramid estimates which percentage of the students that are capable at performing at the given level. [10]

2.1.2.4 Constructivism

Constructive learning is based on the idea that knowledge is actively constructed by the learner and not passively transmitted by the educator. This is known as Piagetian constructivism, originating from the work of Jean Piaget (1896-1980). The theory of Piaget discusses how human beings create and reproduce sense, consequence and understanding by processing information. Piaget was a biologist, and many of his thoughts and ideas were founded on biology. He believed that biological maturation establishes the preconditions for cognitive development, and separated the process of learning from the process of learning to learn. Further the motivation to learn is biologically adaptation to obtain equilibration, or the balance between mental organization and the environment.

This biological approach of Piaget is quite similar to the ideas of this predecessor Lev Vygotsky (1896-1934), yet founded on two quite different human views. Vygotsky based his work on Marxist theory of dialectical materialism, how historical changes in society and materialism impacts human nature, where the environment surrounding an individual affects the individual's motivations for changing behavior, or learning.

These theories has been developed and reinforced further into other directions that most some degree appears in the educational services such as the philosophical, cybernetic, educational, and sociological constructivism.

Philosophical constructivism go back to Aristotle and the ancient Greek instrumentalist philosophy and encircle all the common epistemological presuppositions underlying the other kinds of constructivism, supports the social construction of all human knowledge and beliefs (von Glaserfeld). In other words, it is we who construct the known world on the basic of our experiences and active process of developing knowledge, rather than discovering the world as it is (Thomas Kuhn, 1962).

Cybernetic constructivism is based on the concept of autopoiesis originating from cell biology and substantiates the concept of philosophical constructivism as a self-referential process of maintaining identity. That is that action and cognition depend on each other without any outside system of reference. Lev Vygotsky looked in the direction to social interactions as the source of cognition and behavior.

Educational constructivism, also known as psychological constructivism (Phillips, 1995), divides into personal and social constructivism, according to whether it is the individual person or a group who does the constructing or the processing of cognitive and memory structures.

Sociological constructivism or social constructivism is concerned with the public bodies of knowledge, the various disciplines of science and technology, and how they are socially constructed and interpreted in terms of changing social conditions and interests. [11]

2.1.2.5 Constructionism

Constructionism was introduced by Seymour Papert, known as the inventor of LOGO, as a digression to constructivism that concentrates on the idea of mental construction. Papert believed that children have a natural urge to construct a meaning to their world. The traditional educational system as Papert saw it was too structured and therefore asphyxiated this natural curiosity. The means which by children were being taught relegated them to a role of passive recipients rather than motivating them to construct learning for themselves.

Constructivism does not call in question the value of instruction as such. That would be silly: Even the statement (endorsed if not originated by Piaget) that every act of teaching deprives the child of an opportunity for discovery is not a categorical imperative against teaching, but a paradoxically expressed reminder to keep it in check. The constructionist

attitude to teaching is not at all dismissive because it is minimalist - the goal is to teach in such a way as to produce the most learning for the least teaching. Of course, this cannot be achieved simply by reducing the quantity of teaching while leaving everything unchanged. The principle other necessary change parallels an African proverb: If a man is hungry you can give him a fish, but it is better to give him a line and teach him to catch fish himself. (Papert, 1993)

Papert believes that personal computers and information technology is the appropriate tool to help the growing up children become motivated learners, critical thinkers, problem solvers and metacognitionists. [12]

2.1.2.6 Collaborative and cooperative learning

Collaborative learning is based on group work, where the students work together in small groups to accomplish a common goal. The groups may consist of students at academically different levels and they are responsible one another's learning as well as their own. [13]

Cooperative learning is defined by a set of processes which help people interact together in order to accomplish a specific goal or develop an end product which is usually content specific. It is more directive than a collaborative system of governance and closely controlled by the teacher. [14]

Proponents of collaborative and cooperative learning claim that the active exchange of ideas within small groups not only increases interest among the participants but also promotes critical thinking.

There is persuasive evidence that cooperative teams achieve at higher levels of thought and retain information longer than students who work quietly as individuals (Johnson and Johnson, 1986). Working in groups enables the students to discuss topics, take responsibility for their own learning, increases communication skills and to become critical thinkers (Totten, Sills, Digby, & Russ, 1991). Thus the students become more

motivated, they attain more information and they tend to remember the information for a longer time. (Tools for Teaching, Barbara Gross Davis, 1993)

2.2 Video- and Computer Games

2.2.1 History of videogames

The concept of interactive programs for entertainment purposes was first properly realized in 1962, when a group of computer programmers at MIT developed a two player game named "Spacewar!" [15], which involved control of a spaceship capable of maneuvering and firing missiles in space. The objective was simply to destroy the other spaceship while avoiding his missiles, as well as the gravitational pull of the sun. It was a very simple concept, but an instant hit amongst the students at various universities over the country. However, "Spacewar!" wasn't a commercial game, as the hardware required to run the game would amount to about $120,000 US and take up the same space as a refrigerator would.

The first commercial games would appear in the form of arcade machines, hitting the market in the 1970s. Games such as "Pong" and "Asteroids" by Atari, were simple ideas which were turned into popular moneymakers due to the excitement and freshness of being able to interact with a TV like screen at the local arcade. An example of how popular this phenomenon had become would be best portrayed by the launch of the game "Space Invaders" in Japan – 1978, where the country would suffer from a coin shortage as shop owners would clear out their stores to set up more arcades with the popular game.

Some years later, in 1985, Nintendo released the "NES", or "Nintendo Entertainment System", which would become one of the home consoles that would manage to survive where its competitors more or less failed. With recognizable characters like "Super Mario" and "Donkey Kong" in very popular games, and licensing other companies as official "NES" game producers, they managed to provide a wide variety of gaming options while further developing their own core games, namely the Super Mario series.

The games for a personal computer were still small and not too popular, the cost of an IBM compatible computer compared to a video gaming system was simply too much for the average person, however, people would still develop games for it. The game “Tetris” was developed by a Russian named Alexey Pazhitnov then ported to PC – and later to other platforms, this game would become one of the most popular games to date. Nintendo managed to secure the rights to ship this game for their portable console, the “Game Boy”, which became so popular that Nintendo managed to take over the market regarding portable gaming systems.

After a split from Nintendo, Sony decided to jump into the console scene and launched their “Playstation” as a solid competitor, and the fierce competition for this very lucrative market has helped speed up the evolution of both hardware and software, resulting in much better and more realistic graphics, as well as more computer processing power for more difficult tasks, enabling developers to develop what is considered “better” games. At present, as of spring 2005, the video console business is currently dominated by Nintendo, Sony and Microsoft with their latest products, “Gamecube”, “Playstation 2” and “X-Box” respectively, with both Sony and Microsoft announcing new consoles coming shortly.

During the 1990s, the personal computer at home became more and more common. As this happened, more and more game developers realized the potential with developing games for the PC, and more and more titles would be released for use on the PC exclusively. The quick advances in PC processing power, and especially related to graphics, where one started putting extra graphic cards in PC systems to be able to further optimize the visual display, resulted in most high-end gaming projects being released for the PC platform first, and then ported to consoles afterwards, if at all. The profits from sales off popular titles today enable developers to pour millions of dollars into the production, it’s not uncommon to hire high profiled actors and do movie style video shoots for games, as game developing companies strive towards making the most realistic and impressive games possible.

2.2.2 Game genres

There are thousands of games out on the market today, all of them more or less different from the next product. One of the challenges facing developers when new games are being planned and developed involve deciding which genre the game should belong to, or if it's going to be a cross-genre hybrid. The decision whether to go for something safe well within a genre, hopefully drawing fans of that particular genre in, or to go for something new such as mixing different kinds, risking rejection from fans of all the genres involved, or reaping the rewards from all those fans instead, if it's received well. Following is a rough description of the main genres and examples of games – roughly arranged chronologically from when the first breakthrough game in its genre appeared, it should be noted that the genres and which games belong to which genre is a subjective matter and will most likely vary slightly from person to person.

2.2.2.1 Arcade

Although not really a genre, it's common to refer to smaller games usually found mainly at arcades as Arcade-games. The common denominator is a simple interface which is very intuitive and easily addictive despite its repeating nature. In addition to these, games commonly referred to as "Shoot 'em up!" should go under this genre, originating from "Space Invader" a shoot 'em up game involves a ship shooting and dodging obstacles that typically scroll horizontally or vertically. Popular examples of the arcade genre involve "Pong", "Tetris", "Pac-Man" and games such as "R-Type", "Xenon" and "Space Invaders" from the Shoot 'em up genre.

2.2.2.2 Fighting

This genre usually involves martial arts or other melee combat between two or more people, possibly involving weapons such as sticks or swords and the occasional ranged attack. It became widely popular after the "Street Fighter II" game was released, and was a huge hit on arcades everywhere. However, the genre managed to further evolve and make it big on consoles and PC systems as well, with series such as "Tekken", "Street

Fighter", "Soul Calibur" and "Dead or Alive" selling well and constantly releasing new versions. Although the majority of such games are focused more on the sport of fighting rather than the brutality and violence, the game "Mortal Kombat" involved some rather graphic violence and was the reason why a law was passed to add maturity ratings to computer games being sold in USA.

2.2.2.3 Adventure

The adventure genre involves games which usually let you control the main character through a storyline, solving puzzles and quests, resulting in games that don't require the brute force of an action/shooting game, but focus more on thinking your way through different situations. The early adventure games were simple text adventure games, which were nothing more than text saying where you were and what you could do, then it was up to you to do the right thing to progress in the story. The "King's Quest", "Police Quest" and "Monkey Island" series are examples of such pure adventure games. Starting with the "Tomb Raider" game, it became popular to mix in a little bit of action to adventure games, just enough to add some risk to it without losing the adventure status, it also seems that most games which are based on movies or TV series tend to reside in the action-adventure genre.

2.2.2.4 Sports / Racing

A genre that is especially popular amongst people who tend to not be the stereotypical videogame-player, but more a person who enjoys cars / sports and tends to sit down to get further into his hobby, often with friends over enjoying the multiplayer abilities these games usually feature. The games in this genre adapts well known rules from established real life sports such as soccer, hockey and basketball and lets you play and/or manage teams through matches and seasons. The racing games tend to involve relative quick cars in realistic surroundings and racing against other players or the clock. Popular titles within this genre would include the "Need for Speed", "Destruction Derby" and "Gran

Turismo" series as far as racing goes, while "FIFA", "NFL Blitz!" and "Championship Manager" headline sports.

2.2.2.5 Role-Playing

These type of games stem from the "pen and paper" role-playing games, Dungeons & Dragons being the most popular, involving control over one or more characters, each with their own statistics and skills. As opposed to adventure games, this genre lets your character progress and become stronger as the game goes on and the character obtains experience points, usually by defeating foes or solving tasks. The most common setting would be a fantasy medieval sword and magic world, where players choose a typical class or profession to play, usually choosing between the archetypes fighter, magician, healer, thief or any derivative or hybrid of those. The "Krynn", "Ultima", "Diablo", "Dungeon Siege" and "Baldur's Gate" series are good examples of this, with games such as the "Final Fantasy" series and "Star Wars – Knights of the Old Republic" being games of the same genre, but not basing itself in the medieval setting, but rather having their own worlds and rules defined.

2.2.2.6 First Person Shooter

Commonly referred to as FPS games, this genre includes games where the player looks from a first person perspective – seeing the world from the eyes of the in-game character, usually wielding a weapon. The objective usually is to maneuver through somewhere while shooting enemy obstacles that appear. The breakthrough game in this genre would be the game "Doom", where you play a marine stranded in a world of horror creatures, and you have to fight your way out, with anything from pistols and chainsaws to rocket launchers and plasma guns. This is probably the genre that has reaped the most public disgust when it comes to violence in computer games, with games such as "Postal 2" actually being denied entry to the market due to violence and deemed inappropriate material. On the other side of events, the game "Counter-Strike", which is an add-on to the fan favorite "Half-Life", has been praised as one of the better team based computer

games, and has helped this genre to develop tournaments with high prizes and a very competitive community. In addition to the “Doom” and “Half-Life” series, “Quake” and Unreal are popular series within this genre, “Halo” for “X-Box” is also noteworthy as the first FPS to successfully conquer the console market, as these games tend to not be very console controller friendly due to needing the rapid movement only a mouse can provide.

2.2.2.7 Strategy

Strategy games usually focus on resource gathering and management, research, development and military combat to win. The better you are at knowing the system and how to manage your resources and then make the right decisions, the bigger your chance at winning gets, resulting in this being more of a knowledge and thinking game rather than fast paced action, with the evolution of the strategy games came the real time strategy games as opposed to the earlier turn based games. In the real time strategy, every player would make his decisions while the action was taking place, where as the turn based would involve making your decisions and then ending your turn, for another player or the AI to make his move. The “Civilization” series along with the “Heroes of Might & Magic” are some of the most successful turn based strategy games, while the “Command & Conquer”, “Starcraft” and “Warcraft” series has reaped the most success as far as real time strategy games go.

2.2.2.8 MMORPG

The MMORPG or MMOG genre, Massively Multiplayer Online Role Playing Game and Massively Multiplayer Online Game respectively, introduces a new genre based entirely on online internet play. The concept involves creating virtual worlds that thousands of players can interact in. This furthers the social aspect of playing games, as most of the games in this genre force you to work together with other players to accomplish progress and certain goals. Its most common form is the online game combined with the RPG genre, where you play your own customized character, then developing it with skills and experience to achieve the maximum possible level in the game, at which point one

becomes powerful enough to do some of the high-end tasks in the game. The real commercial success and breakthrough of this game would be “EverQuest”, which has the medieval fantasy RPG setting. Unlike traditional games, the online games constantly evolve, and focus on the player community – constantly upgrading content and holding in-game events to maintain a base of players. As compensation for this, each player needs to pay a monthly fee to be able to keep his or her character in the game, a fee which was from $5-10 USD upon launching these games, but with the launch of “Star Wars Galaxies”, the standard fee was raised to $15 USD per month, and has been kept there by other later releases within this genre as well. It should be noted that players tend to pour a fair amount of time and effort into building their characters and equipping them with items, where a standard released game will usually involve a few days of dedicated playing to finish and explore, a MMORPG will usually take months of the same dedicated playing to complete. Along with this time and effort, people discovered that it could be a market for selling their virtual property, and companies such as Ebay or other online auction sites are currently flooded with auctions involving either in-game virtual items, currency or accounts containing several characters. According to research done by Edward Castronova at the Center for Economic Studies and Institute for Economic Research, the virtual world which exists in “EverQuest” and its economy, the world and its inhabitants “produce a GNP per capita somewhere between that of Russia and Bulgaria” [16]. Other famous MMORPGs include “Dark Age of Camelot”, “Shadowbane”, “Lineage” and “World of Warcraft” in the medieval fantasy setting, while games such as “Star Wars Galaxies”, “Anarchy Online” and “EVE Online” are online games in a science fiction setting. In addition to this, there are a few other massively online games who doesn’t incorporate the RPG genre fully, but try to add in another. “Planetside”, for instance, is an example of a massively multiplayer FPS.

3 Symposium

3.1 Educational plan for 2MX

All Norwegian schools are to follow a common educational plan that provides guidelines for curriculum and quality. These guidelines are expressed in terms of goals and for the 2MX course the students are expected to communicate information in oral, written and graphical form. They are to implement mathematical argumentation, have an insight in mathematical history and to understand the impact mathematics have on the society.

The primary goals that the plan expresses are:

- The ability to discuss and solve mathematical problems in groups and then to present the results by reasoning.
- The ability to read and understand a simple mathematical text, explain the contents and to utilize it in a solution.
- To know the terms implication and equivalence and be familiar with some basic mathematical proof.
- To know the mathematical proofs for some central techniques and perform mathematical reasoning.
- Know the diversity of the mathematical history and to gain an insight on what impact mathematics have on science, society and culture.

The plan is further divided into sub goals for each topic of the curriculum. As this project is limited to the topic “Combinations and probability” we will only mention this topic here. Upon completion of “Combinations and probability” the students are expected to know the fundamental concepts behind the theory of combinations and probability, and to solve practical problems by applying these theories. The students should know the difference between ordered and not ordered selections, when repetitions are allowed or not, and be able to calculate probabilities from this information. They are to know the

terms independent and dependent probability and use Bayes' equations. The students should be able to calculate hyper geometric and binominal probabilities.

The educational plan of Norwegian schools is to a large extent based upon the philosophy of active learning. The students are to gain knowledge through actively exploring their surroundings. The Norwegian educational plan can therefore be said to embrace the teaching of constructive learning. [17]

3.2 Constructivism in math education

"Students need to construct their own understanding of each mathematical concept, so that the primary role of teaching is not to lecture, explain, or otherwise attempt to 'transfer' mathematical knowledge, but to create situations for students that will foster their making the necessary mental constructions. A critical aspect of the approach is a decomposition of each mathematical concept into developmental steps following a Piagetian theory of knowledge based on observation of, and interviews with, students as they attempt to learn a concept."[18]

Constructivism has become the leading approach in education over the last decades. For logical subjects, where the understanding of concepts is tested rather than the ability to repeat theoretical information, constructivism is highly appreciated. Understanding of a problem and understanding of the solution, as opposite to memorizing the solution to a problem, is easier to transfer to a different problem.

The concern about the falling numbers of student who choose to study math, and also the worrying skill level of these students has been widely expressed over the latest years. Compared to 2004, in 2005 there was a reduction of 12% whom applied for technology and science in Norway. This tendency is equivalent in other western countries. [19]

The way math is taught is the way the educators may impact the situation. The view that some students have natural math skills and other don't, where the educators' role is to adapt the difficulty level of the exercises and tasks to perform may not contribute to develop the students who are not succeeding.

In contrast, constructivism focuses our attention on how people learn. It suggests that math knowledge results from people forming models in response to the questions and challenges that come from actively engaging math problems and environments - not from simply taking in information, nor as merely the blossoming of an innate gift. The challenge in teaching is to create experiences that engage the student and support his or her own explanation, evaluation, communication, and application of the mathematical models needed to make sense of these experiences. The students that do not get math easily are most likely not unable to learn it, in most cases they are just not conscious of how their mind works and how they can gain knowledge.

Given this view, there are many approaches to improving teaching: look for different ways to engage individual students, develop rich environments for exploration, prepare coherent problem sets and challenges that focus the model building effort, elicit and communicate student perceptions and interpretations, and so on. [6]

3.3 Educational methods in e-learning

Computers and multimedia offer a different approach to active learning than traditional classroom education. Many e-learning solutions have been presented up to today. Unfortunately most of the systems seem to focus merely on effacing geographical location of the students by providing lecture notes or video of lectures, rather than focusing on interactive learning that directly involves the students [20]. Easy access to lecture notes is under no circumstances a step backwards for the enlightened world, but

the use of personal computers in education has a lot more to offer. Personal computers and the Internet offer solutions for group networks, active and interactive learning, provide fun for the student and instant feedback for every student.

Computer networks may be used in collaborative work all over the world. Working instantly with other people in other parts of the world may increase motivation and focus when working.

Active learning by interactions with the computer enhances the aspects of constructivism. Personal computers are a very suitable tool for combining active learning with actually creating something. Constructivism builds on the theory that when only reading about a subject, or doing the tradition school assignment where no practical results are accomplished, the natural interest to explore and learn decreases. When a practical result is sensed, the feeling of success will motivate to more educational activity.

Multimedia brings the real world to the learner through the use of audio and video. Such connections to the real world should allow the students to connect the information provided to other knowledge structures. Multimedia also provides multi-modal learning, by presenting information in different ways different areas of the recipient's brain will be engaged. Computer games offer to directly activate the students by involving them in the process of problem solving. Unlike multimedia, computer games invite the students to play an active role. Computer games may combine education with graphics, sounds and a storyline to become entertaining while educational. Actual professional applications may be used as a tool in project work, this may motivate the students by using professional software and the ability to see results from their work. This might be CAD software for design and publishing software for the school paper etc.

A bonus when using computers is the fact that everyone gets the same amount of attention and feedback. The feedback may also be given instantaneous while the problem still is fresh in memory. The concepts of behaviorism may be applied in an educational

game by adding consequences based on the performance, such as a reward when something is done correctly.

The major changes in society over the last decades should also be taken into account when considering educational systems for the future. Today's youth, know as the millenials (born 1981->) are far more demanding than the pervious generations (Traditionalists (1900-1944), Boomers (1945-1964), Generation X and Y (1965-1980)) in the way they require feedback and attention at "the push of a button". Employees have expressed concern that the upcoming generation does not have the vitality and independence that their parents had, since hiring additional personnel to give continuous feedback will lower revenues. [21]

Children born in the 1990's are also known as the net generation. These are not content in being passive recipients of the traditional teaching processes, rather they want to discover it for themselves by becoming interactive with the learning. Computerized learning may not only be a supplementary tool in future education, but a requirement by the students. [22]

3.4 Summary on game theory and relevance to our project

The task involving the creation of educational software isn't an easy one. It's quite impossible to compete with the commercial gaming development based on funding alone. Educational software tends to not sell as well as commercial games, and as a result, few, if not none, of the serious game developing companies will develop such games.

The main objective of educational software should therefore not be to compete with current games, but rather try to make it an interesting alternative to current studying methods, hopefully infusing more enthusiasm into the student than traditional methods of learning would.

Based on the current gaming genres, there is no definite genre of choice for an educational game. It would be very hard to fit all subjects in a course into one definite game without making it simply an interactive experience involving more or less copying questions and answers from a relevant book. This would do nothing more than transfer the contents of the course when it comes to questions and answers into an interactive way of checking if you wrote the correct answer, and not fulfill the actual requirements of a standard computer or video game.

The conclusion regarding choice of genre would have to be a combination of things; our ideal solution involves using the virtual world and persistent character concept from the Massively Multiplayer genre as a framework, or bounds for where the player can walk – then add on different modules to cover the various aspects of the intended material.

This setup would, in addition to giving the basic framework and some common guidelines, allow for easy communication with server software and thus enable easier ways of doing reporting and analysis of the students' progress. It could also provide easy and quick communication between other students logged in at the same time, as well as supervisors or teachers if the need should arise. If building on the persistent character model, it's also possible to have each player create their own character or unique token to identify with, and maintain their achievements even if they log off, to continue at a later point. It would also be possible to identify easily how far in the material they have come, by implementing experience point gains after each successfully solved task, as well as gaining something equivalent of character levels after certain amounts of experience. Due to the data being stored at a server, it's also quite easy to set up a simple high score system, showing top scores to add further incentive for players to keep playing and hone their skills even more.

The modules would be implemented as small games, similar to the arcade genre, designed to cover a specific portion of the curriculum. Various sub-genres could apply for these minor games, adventure games involving questions and a destination, remakes of old traditional games with a new twist to involve learning about a certain part of the

traditional games mechanics, an example could be calculating chances in a lottery, yahtzee or another familiar game of chance. Due to being supported by the framework and server setup, it's also easy to implement reports and scoring to use for an instructor to check progress and as means to keep track of the highest scoring players, to encourage students into working harder and attaining that little piece of recognition that comes with having your name added to such a list.

All in all, such a setup will allow for a solid basis for developing separate games, not only in the math subject, but one can easily implement different kinds of experience points for people to attain – in any course taught. The implementations of the individual modules can thus follow different pedagogic principles based on which would be most relevant for the intended field of study and purpose of the module.

4 Methods

4.1 Research Methodology

In this section we will discuss methodology for this study, which means how we plan to achieve our goals in researching the subject at hand. Our expertise is technical, not that of pedagogic. So by endeavoring on such a project we not only presume that didactic knowledge will be available for us, but that we will be able to utilize it in a constructive way.

4.1.1 Overview of the research questions and the methodology applied

To survey and validate the impact of game based learning of a mathematical problem we need to divide the research into five subparts with its own objectives.

The first objective is to assess and incorporate fundamental pedagogical principles that apply to the scope of our research, so that they can be used as a platform for further work.

The second objective is to evaluate different approaches to commissioning the game in such a way that the learning effect is maximized without rendering the game unplayable or not entertaining.

The third objective which is a pure design and development tasks is to finalize the game.

The fourth objective is to test the application on individuals or groups, before, during and after using the application there will be collected information regarding the participants.

The fifth objective is to analyze the data to see if the initial hypothesizes were correct and to revalidate the methods used in order to validate the research project.

4.1.2 Sources of information

Especially in the first part of the project we will rely heavily on the work of others. Sources for information will be libraries, the Internet, resource persons, schools, other projects and organizations. The ideal situation is to establish a connection to a school nearby, and exchange information about the project with teachers and students there. Previous test-scores and teachers experiences should prove to be well suited for selecting mathematical problems to be scrutinized and eventually defining the scope of the mathematical problem.

4.1.3 Selection and description of participants

For the second part of the project we will solicit teachers and students whom are comprised by mathematics within the scope of our study to participate, not only for the second part, but for the duration of the project.

The advantage of using a selected group is that there will hopefully be less noise in the data collected, but by using a more quantitative approach the results will be more representative for the general population. Initially we will only use a selected group of participants, but as the project evolves into phase four, the application will be available for the general public on a web-server for testing, thereby making the data collection quantitative also.

4.1.4 The Development stage

The most important thing is how we design the part of the system that interacts with humans, the interface. A good source of information is SIGCHI (Special Interest Group on Computer-Human Interaction [23]). An illustration of how to develop a system for interacting with humans is shown in figure 4.

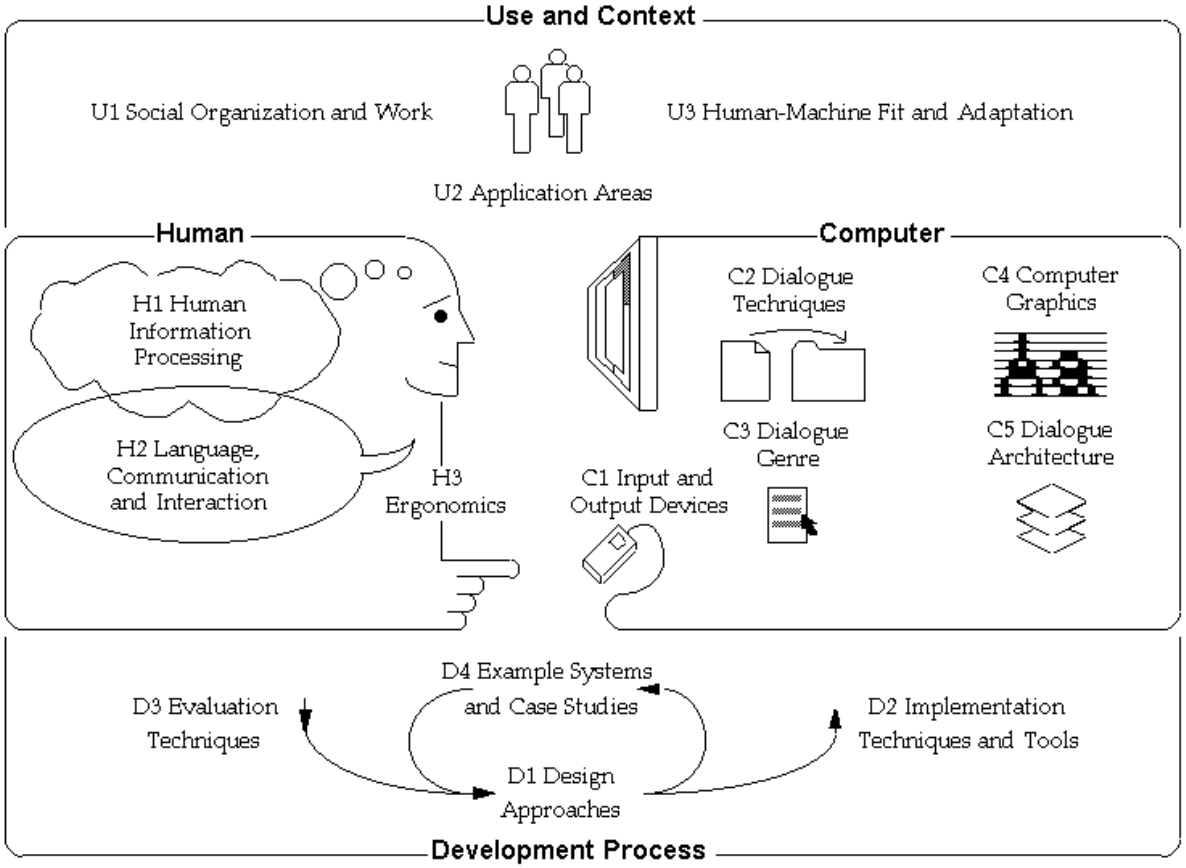


Figure 4: ACM SIGCHI 2001 Human-Computer Interaction

4.1.5 Data collection strategies

For the first part of the study we will use the Internet, libraries and resource persons to define an image of how to apply pedagogical principles on games. Further these hypothesizes will have to be verified, or at least approved by a resource person within that field of expertise. Here much of the information will be collected through interviews, both personal and through e-mail.

For the second part of the study we will try to define what the target audience wants and would expect in the respect of game based learning. The most evident method is to interview some of the participants, trying to create an image of what kind of games students actively would use, and how they would be used. Also teachers could have beneficial input in respect to how the game can incorporate pedagogical effects. Commercial games also uses some quite sophisticated psychological effects to attract gamers, many of which we can benefit from in this research.

In the fourth part of the study we will try to collect as much relevant information about the users of our application as possible. Before a user can play he or she needs to answer a few questions, both personal (age, sex, interests, etc.) and mathematical (interests, personal evaluation, etc.). During the game information about the player is collected, such as results in specific areas, ranking, chosen solutions, etc. Then after playing the game for a certain amount of time or times, the user is solicited to answer a few questions again. These questions are used to verify that the design of the game was successful in respect to playability, and to get a user evaluation of the learning effect.
As an addition we will ask to get test-results from tests taken that falls within the scope of the learning game, by students involved in the study to compare with tests taken by students not involved in our study.

The size of the samples depends greatly on the extent of cooperation with schools and teachers, which mainly affects the qualitative research. When it comes to distributing the

game the quality of the research based on this isn't that good, and we have no way of knowing anything besides the information collected by the game itself.

Using forms printed out on paper for collecting information is the most obvious approach for the first and second part of the study. In the fourth part a database connected to the game, where the information is collected and to electronic submission forms, is the most practical way to collect information.

To collect data from sources in a way that makes it reliable we need to have a plan for what to get from which source, and this plan in turn needs to be verified, preferably by someone outside the project. Her we will try to outline what research questions we have and what sources to get them from in matrices.

Research Questions	**Teachers**	**Organizations**	**Internet**	**Library**
What are the most applicable pedagogic principles for our study?	e-mail, personal requests and interviews	e-mail	search	Manual research
How can such principles be utilized in the best way possible?	e-mail, personal requests and interviews	e-mail	search	Manual research
Is there anything that should be avoided?	e-mail, personal requests and interviews	e-mail	search	Manual research
Is there any additional information on learning by games?	e-mail, personal requests and interviews	e-mail	search	Manual research

Table 2: Research matrix for pedagogic principles

Research Questions	**Students**	**Teachers**	**Internet**	**Library**
What kind of games do students play, and what do	e-mail, personal requests and	e-mail	search	Manual research

they like about them?	interviews			
What would be a good game for learning?	e-mail, personal requests and interviews	e-mail	search	Manual research
How should learning and entertainment be balanced?	e-mail, personal requests and interviews	e-mail	search	Manual research
What should a game include? And what should it not include?	e-mail, personal requests and interviews	e-mail	search	Manual research

Table 3: Research matrix for game design

Research Questions	**Students**	**Teachers**
What did the students know beforehand? What is the users' perception of their own knowledge?	Data collected by the game, forms, personal requests or random samples of interviews	-
What were the expectations before playing?	Data collected by the game, forms, personal requests or random samples of interviews	interviews
How did the results of the test group compare to the reference results?	Data collected by the game, forms, personal requests or random samples of interviews	interviews
What changes can be made?	e-mail, personal requests and interviews	interviews
Was the game meaningful, as a learning tool? Was the game entertaining?	Data collected by the game, forms, personal requests or random samples of interviews	interviews

Table 4: Research matrix for the effects

4.1.6 Data analysis strategies

To analyze the information that we collect in part one, there is probably no need for a database. Instead a spreadsheet is probably sufficient to collocate data into representative and useful views.

As for the information collected in part two and four of the project we will probably need a database, depending on the response. Then an analysis tool like SPSS or something similar is needed to sort through and extract the information that is vital to the research.

4.1.7 Methods of achieving validity

This study aims to measure any effects that game based learning might have, not to device any new pedagogic techniques, therefore we will focus on the technical side of the solution. To achieve validity for our results we need to make sure that the results for our reference group is comparable to the test group. Also the relative deviation of such results needs to be accounted for. So for the research to be valid, all stages of the project need to be validated and the information collected will have to be reliable. That further implies that we need to cross-reference the results we get with other sources, and make sure that our results can be verified from each and every point of view.

4.2 Project management

This section describes how the project was carried out.

4.2.1 Development process

The main goal of the project is simplified by dividing it into smaller, feasible tasks. During the pre-project phase the major tasks and milestones were identified. Identifying the milestones of a project, their order of commencement and completeness, generally increases the probability of success.

The process of developing software is generally divided into five phases: requirements, analysis, design, implementation and testing. The short time scope of the project speaks in favor of a very simple development process model. The waterfall model is known for being efficient when it is possible to separate each project phase completely [24]. The drawback of the model is the costs of reopening a completed phase. Such as if the requirements are suddenly changed during the implementation phase.

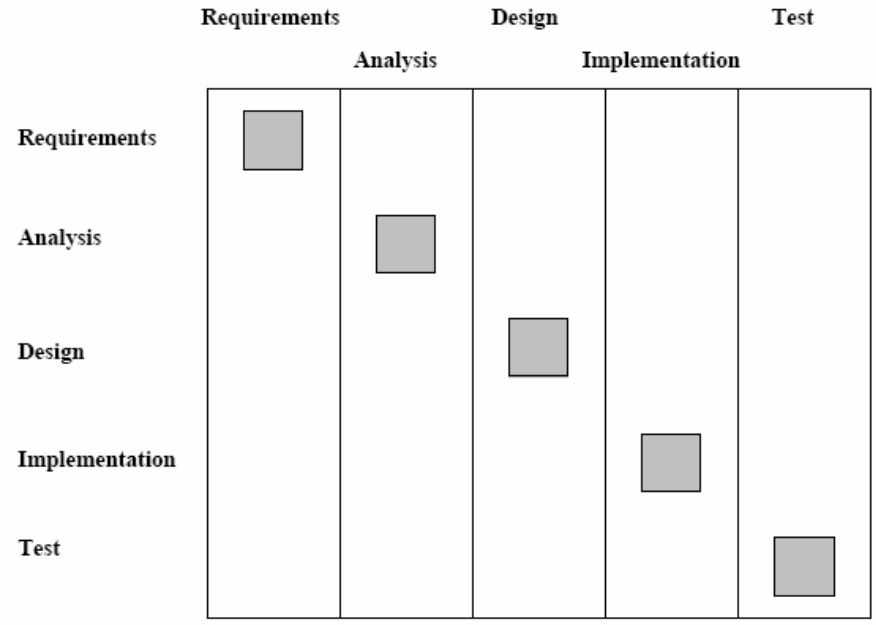


Figure 5: The Waterfall model, Vertical: Project phase, Horizontal: Performed tasks. (Bennet & McRobb 2002).

The following section shows the milestones and tasks of this project in chronological order.

4.2.1.1 Reference groups

The first task of this project was to get in touch with some test and reference groups. The reference groups are essential in both collecting data for the design requirement and in testing the prototype. All our results are measured against this reference group.

We asked Øystein Haga at Dalhske High Schoor / Junior college if he would care to be a part of this project as form as a reference group. The response was positive and we had a meeting to get the teachers' view of this subject, and performed a questionnaire with the students.

4.2.1.2 Literature Research

Literature research was commenced at a very early stage. The main focus for this milestone is to get a good idea of the educational software area and educational methods before designing the game concepts.

Information regarding this subject has been obtained by surfing the World Wide Web and by using the local network of pedagogic competence at HiA. The competence at HiA concludes the parAbel project and a teaching faculty that offer several courses, including a five year Master of mathematical didactics.

The experiences gained from the reference groups and literature research builds a basis for the project requirements.

4.2.1.3 Game concept design

Based on the information gained from the reference groups and literature research game concepts were designed.

4.2.1.4 Development

The development of the educational game prototype commenced in February, shortly after the game concepts were approved by the mentor, Ola T. Aas.

To make the development phase as gently as possible, the code components where carefully divided into different libraries to avoid complications that occur when several people are working on the same project.

4.2.1.5 Prototype Test group

The game prototype was tested on a test group of 2MX students. The testing was followed by a questionnaire to collect feedback from the students.

4.2.1.6 Report writing

The report was written throughout the duration of the project. Experiences gained from the work were documented at all times.

The major project writing task was done over the last month. The knowledge of the project team is expected to peak at this time and the results from the prototype test group were planned to come close to the deadline to allow as much time as possible for the prototype development.

4.3 Division of labor

We have attempted to divide the tasks between us as fairly as possible. The requirement phase was done with everybody present to make sure everyone had a good understanding of the problem and tasks to be done. The development phase was divided into smaller parts where each member of the team had responsibility for their own components in order to maximize productivity. The report writing phase has some parts that are written in group, while for the main topics we tried to specialize within a field each to maximize the quality and efficiency.

Daniel Fløtre

- Game framework
- The world module / Main menu
- The maze game module
- Specialized in educational methods

Erling G. Kristiansen

- The Venn diagram game module
- SPSS analyzing
- Specialized in research formalities

Jan Heggernes

- The Game server
- The casino game module
- Specialized in computer game design

5 Analysis

Initially we intended to use SPSS for the analysis part, but as we realized that the amount of data was not in the quantity we expected, we chose to mainly use spreadsheets instead. The following tables are created in Excel, and are meant to create a picture of the results.

5.1 Results from Initial Questionnaire

These are the initial questions with number of answers collected for each question, and the average value in the answers given. For example sex (Kjønn) relates to male or female, 1 is female, and 2 is male. And the average is 1,63 which means that there are more males than females, to be more exact the distribution is 63% males and the rest females.

	Questions	average	answers
1	Kjønn	1,63	30
2	Har du tilgang til PC hjemme?	1,03	30
3	Har du tilgang til Internett hjemme?	1,03	30
4	Har du Konsoll hjemme Playstation/Xbox/Gamecube etc)?	1,37	30
5	Bruker du Instant Messengers (MSN, ICQ, Yahoo, AIM, etc.)?	1,17	30
6	Spiller du online-spill?	1,43	30
7	Hvor mye tid bruker du PC daglig?	3,40	30
8	Hvor stor andel av tiden du bruker PC går med til spill/underholdning?	3,31	29
9	Hvor mye betyr det å kunne konkurrere med andre når du spiller?	2,73	30
10	Hvor mye kunne du tenke deg å bruke PC til arbeid i matematikk?	2,90	30
11	Hvor mye tid bruker du på matematikklekser ukentlig?	3,03	30
12	Hvor mye tid bruker du på matematikk i forhold til andre fag?	3,33	30
13	Hvordan er vanskelighetsnivået på matematikk i forhold til andre fag?	3,47	30
	Hvor mye spiller du innen hver av disse sjangrene?		
14	Action (Half-Life, CS, Tekken)	2,28	29
15	Adventure (Monkey Island,Tomb Raider)	1,81	26
16	Simulator (Sports/Driving)	2,21	28
17	Roleplaying (Diablo, Morrowind, NWN)	1,96	26
18	Strategy (Warcraft, C&C, Civilization)	2,50	28
19	Puzzle (Tetris, Incredible Machine)	1,81	26
20	Onlinespill (SWG, Planetside, SB, WoW)	2,00	28
	Hvordan vektlegger du følgende elementer når det gjelder spill?		
21	Grafikk	4,00	29
22	Lyd	3,28	29
23	Spillbarhet	4,36	28
24	Multiplayer	3,00	29
25	Vanskelighetsgrad	3,52	29

Table 5: Initial questionnaire

Looking at the rest of the questions with 2 choices, the results are very clear. Only 3% Does not have access to a computer at home, and all of those 97% that does, also have access to internet. 83% of the entire class uses some sort of IM(Instant Messaging) like

MSN or ICQ. There are also 63% that has some sort of game console at home, and 57% says that they play games online.

When we look at the rest of the questions where the choices are ranging from 1 to 5 it's a little bit more complicated and we need to examine the results further. Below is the distribution of answers for both classes that were participating. As we can se some left a few questions blank, either because they didn't know what to answer or they didn't bother to do so. Either way it doesn't affect the outcome very much, but indicates that the results from this questionnaire may or may not be accurate because the participants were not as "involved" as we hoped. But this lack of interest was anticipated and we therefore made an effort to make it as simple and undemanding to complete as possible. But as a result some areas in the questionnaire are lacking depth.

Questionnaire numbers																															
	Class 1																					Class 2									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	2	2	2	2	2	1	2	1	2	1	2	1	1	2	2	2	2	2	2	2	2	2	1	1	2	1	1	1	1	2
2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	2	2	1	1	1	1	2	1	1	1	1	2	2	1	1	1	1	1	2	1	1	1	2	2	2	1	1	2	2
5	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1	2
6	1	1	1	1	1	2	1	2	2	1	1	1	2	1	1	2	1	1	2	1	1	2	2	2	1	2	2	2	2	1
7	5	5	4	5	4	2	4	2	4	3	5	3	2	3	4	4	4	3	3	4	3	2	3	3	3	2	4	2	2	5
8	3	2	5	5	3	2	4	1	2	5	5	2	2	4		3	4	2	2	4	4	2	2	3	5	5	3	4	3	5
9	4	4	5	3	2	1	5	1	5	3	5	2	1	2	3	2	3	4	2	5	5	1	1	1	2	1	1	2	3	3
10	2	4	3	5	4	3	3	3	2	5	1	2	2	3	4	2	2	1	3	3	2	3	3	3	4	2	3	3	3	4
11	2	3	2	3	4	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	5
12	3	4	4	5	3	4	3	3	2	4	4	3	3	4	3	2	3	2	3	3	4	3	3	5	2	4	4	3	3	4
13	3	4	2	1	4	3	2	3	5	4	4	3	4	4	4	3	4	4	3	4	4	2	4	5	1	5	5	4	5	1
14	3	5	4	5	3	1	3	1	2	1	5	2	1	2	3	2	4	1		3	1	2	1	1	1	1	1	1	1	5
15	1	2		1	1	1	3	1	1	3	2	2	1	1	2	2	1	2				5	1	5	2	1	1	1	1	3
16	2	2	3	1	3	1	3	1	5	4	2	2	1	5	4	4	1	1	2			1	1	4	1	1	3	1	1	2
17	5	4		5	1	1	2	1	1	1	1	2	1	2	1	1	4	2				3	1	3	1	1	4	1	1	1
18	5	4	3	5	4	1	2	1	2	2	1	4	1	3	4	1	4	2	3			2	1	5	2	1	3	1	1	2
19	2	2		1	1	1	2	1	1	3	1	3	1	1	1	2	1	1				2	1	4	4	1	2	3	3	2
20	4	1		5	4	1	2	1	1	1	2	2	1	1	2	1	4	1		5	5	1	1	1	3	1	1	1	1	2
21	5	5	4	5	4	1	5	4	5	5	4	3	5	4	4	4	3	3	4	2	5	3	5	5	4	3	5	3		4
22	5	3	4	5	2	1	4	4	3	5	5	2	3	2	3	4	2	2	2	3	3	5	3	3	2	3	4	4		4
23	5		5	5	4	1	5	4	3	5	5	3	5	5	5	4	5	4	3	3	5	5	4	5	5	5	5	4		5
24	4	4	4	5	3	1	4	3	3	3	4	3	3	2	4	3	4	3	1	5	4	2	3	1	1	2	4	3		1
25	4	3	4	5	4	1	4	3	3	3	4	3	4	4	4	3	3	5	2	3	3	3	5	4	3	3	4	3		5

Table 6: Initial questionnaire results

Below we can see the distribution of answers for the whole class, with the meaning of each choice defined. We already have discussed the 6 first questions.

	1s			2s			3s			4s			5s		
1	jente	11	36,7 %	gutt	19	63,3 %									
2	ja	29	96,7 %	nei	1	3,3 %									
3	ja	29	96,7 %	nei	1	3,3 %									
4	ja	19	63,3 %	nei	11	36,7 %									
5	ja	25	83,3 %	nei	5	16,7 %									
6	ja	17	56,7 %	nei	13	43,3 %									
7	ingenting	0	0,0 %	0-1/2 t.	7	23,3 %	1/2 - 2 t.	9	30,0 %	2-5 t.	9	30,0 %	5+ t.	5	16,7 %
8	ingenting	1	3,4 %		9	31,0 %	noe	6	20,7 %		6	20,7 %	Mye	7	24,1 %
9	ingenting	8	26,7 %		7	23,3 %	noe	6	20,0 %		3	10,0 %	Mye	6	20,0 %
10	ingenting	2	6,7 %		8	26,7 %	noe	13	43,3 %		5	16,7 %	Mye	2	6,7 %
11	ingenting	0	0,0 %	0-1/2 t.	3	10,0 %	1/2 - 2 t.	24	80,0 %	2-5 t.	2	6,7 %		1	3,3 %
12	ingenting	0	0,0 %		4	13,3 %	samme	14	46,7 %		10	33,3 %	mye mer	2	6,7 %
13	lettere	3	10,0 %		3	10,0 %	samme	6	20,0 %		13	43,3 %	vanskeligere	5	16,7 %
14	ingenting	13	44,8 %		5	17,2 %	noe	5	17,2 %		2	6,9 %	Mye	4	13,8 %
15	ingenting	14	53,8 %		7	26,9 %	noe	3	11,5 %		0	0,0 %	Mye	2	7,7 %
16	ingenting	12	42,9 %		6	21,4 %	noe	4	14,3 %		4	14,3 %	Mye	2	7,1 %
17	ingenting	15	57,7 %		4	15,4 %	noe	2	7,7 %		3	11,5 %	Mye	2	7,7 %
18	ingenting	9	32,1 %		7	25,0 %	noe	4	14,3 %		5	17,9 %	Mye	3	10,7 %
19	ingenting	13	50,0 %		7	26,9 %	noe	4	15,4 %		2	7,7 %	Mye	0	0,0 %
20	ingenting	16	57,1 %		5	17,9 %	noe	1	3,6 %		3	10,7 %	Mye	3	10,7 %
21	ingenting	1	3,4 %		1	3,4 %	noe	6	20,7 %		10	34,5 %	Mye	11	37,9 %
22	ingenting	1	3,4 %		7	24,1 %	noe	9	31,0 %		7	24,1 %	Mye	5	17,2 %
23	ingenting	1	3,6 %		0	0,0 %	noe	4	14,3 %		6	21,4 %	Mye	17	60,7 %
24	ingenting	5	17,2 %		3	10,3 %	noe	10	34,5 %		9	31,0 %	Mye	2	6,9 %
25	ingenting	1	3,4 %		1	3,4 %	noe	13	44,8 %		10	34,5 %	Mye	4	13,8 %

Table 7: Initial questionnaire results

To get e better picture of the numbers in the table above we have included a diagram with a more graphical representation of the same data below.

We will now examine the questions question by question, and try to uncover relations and interesting trends that stand out.

7. *How much time do you spend using a PC on a daily basis?*

   Some 16% uses a computer more than 5 hours a day, 30% use it between 2 and 5 hours, and another 30% use it between ½ hour and 2 hours. Nobody said that they

never use a computer, and most people use it a lot. And a few uses it extremely much.

8. *How much of the time spent using a computer is entertainment related?*
   The use of a computer for entertainment related tasks are evenly distributed from less than average to a lot. With a little overweight on less than average. Nobody said that they didn't use a computer for entertainment.
9. *How much does it mean to be able to compete with others when playing?*
   Surprisingly it didn't mean much to people to be able to compete against each other, although 20% said it meant a lot. Most said it meant less than average.
10. *How much would you like to use a PC as an educational tool within math?*
    Some 43% wanted to use a PC as a tool for some education, and 26% wanted to use it a little less.
11. *How much time do you spend working with math weekly?*
    80% spend between ½ hour and 2 hours working with math weekly. The rest a little less or a little more.
12. *How much time do you spend working with math compared to other subjects?*
    46% spend the same amount of time working with math as with other subjects, and 33% spend more time with math than other subjects.
13. *How difficult is math compared to other subjects?*
    43% thinks math is more difficult than other subjects, and 20% thinks it is the same.
14. *How much do you play Action games?*
    44% never play action games, and 34% play it some or almost never. 22% play it more than average or a lot.
15. *How much do you play Adventure games?*
    53% never play adventure games, and 38% play it some or almost never. 9% play it more than average or a lot.
16. *How much do you play Simulator games?*
    43% never play Simulator games, and 35% play it some or almost never. 22% play it more than average or a lot.

17. *How much do you play Role-playing games?*

    57% never play Role-playing games, and 23% play it some or almost never. 20% play it more than average or a lot.

18. *How much do you play Strategy games?*

    32% never play Strategy games, and 39% play it some or almost never. 29% play it more than average or a lot.

19. *How much do you play Puzzle games?*

    50% never play Puzzle games, and 42% play it some or almost never. 8% play it more than average or a lot.

20. *How much do you play Online-games?*

    57% never play Online-games, and 21% play it some or almost never. 22% play it more than average or a lot.

21. *How much do you emphasize Graphics?*

    72% emphasize graphics more than average or a lot. 21% thinks graphics has some importance.

22. *How much do you emphasize Sound?*

    41% emphasize sound more than average or a lot. 31% thinks sound has some importance. 24% thinks sound is less important.

23. *How much do you emphasize Playability?*

    82% emphasize playability more than average or a lot.

24. *How much do you emphasize Multiplayer support?*

    38% emphasize multiplayer support more than average or a lot. 36% thinks multiplayer support has some importance. 10% thinks multiplayer support is less important, and 17% thinks it has no importance.

25. *How much do you emphasize adaptive difficulties?*

    53% emphasize adaptive difficulties more than average or a lot. 45% thinks adaptive difficulties have some importance.

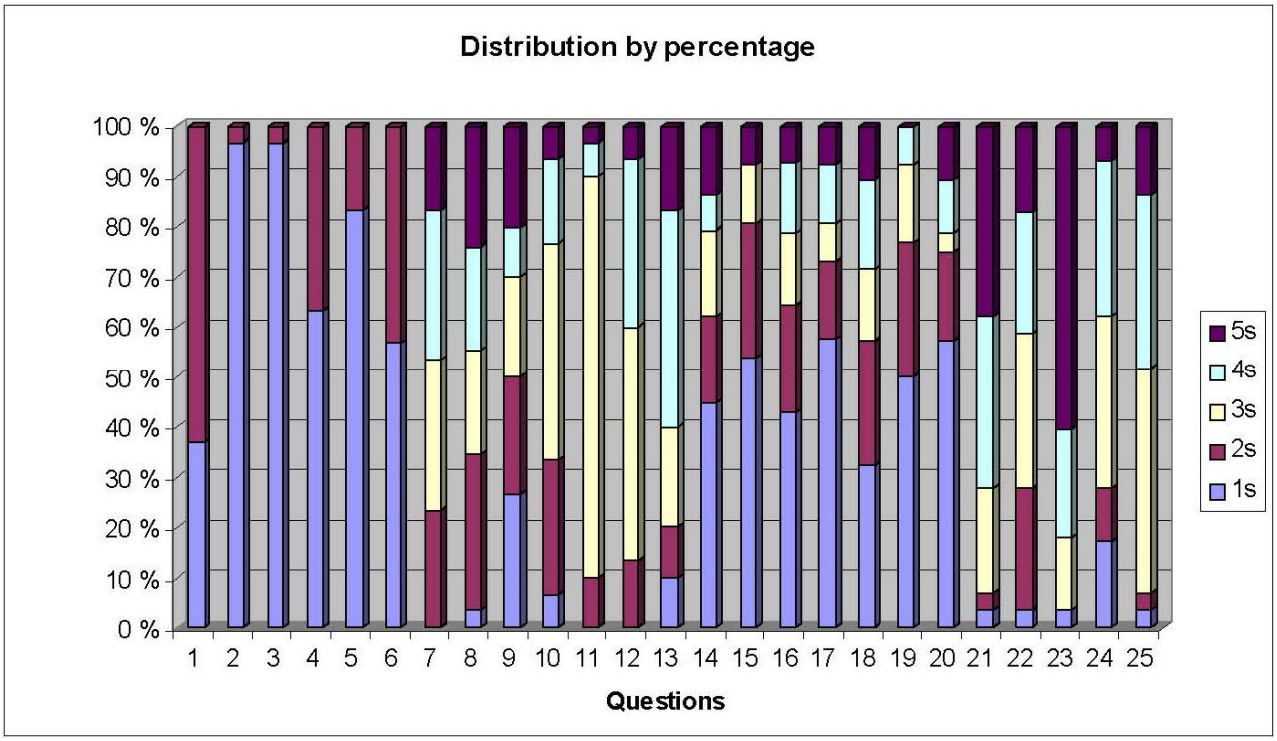


Figure 6: Initial questionnaire

By examining this diagram it's fairly easy to pinpoint trends and values that stand out. The most surprising feature was that so many did not emphasize multiplayer support, given that almost 57% answered that they play online games (See: question 6). Also we were a little puzzled by the fact that almost nobody seemed to play a lot of the main types of games. Other than that we didn't find anything unexpected.

5.1.1 Results for males

By looking at differences between males and females we see several interesting features. The first noticeable features are that 100% of the males have access to a PC at home, with internet access. Males also play a lot of online-games, and generally seem to play more games.

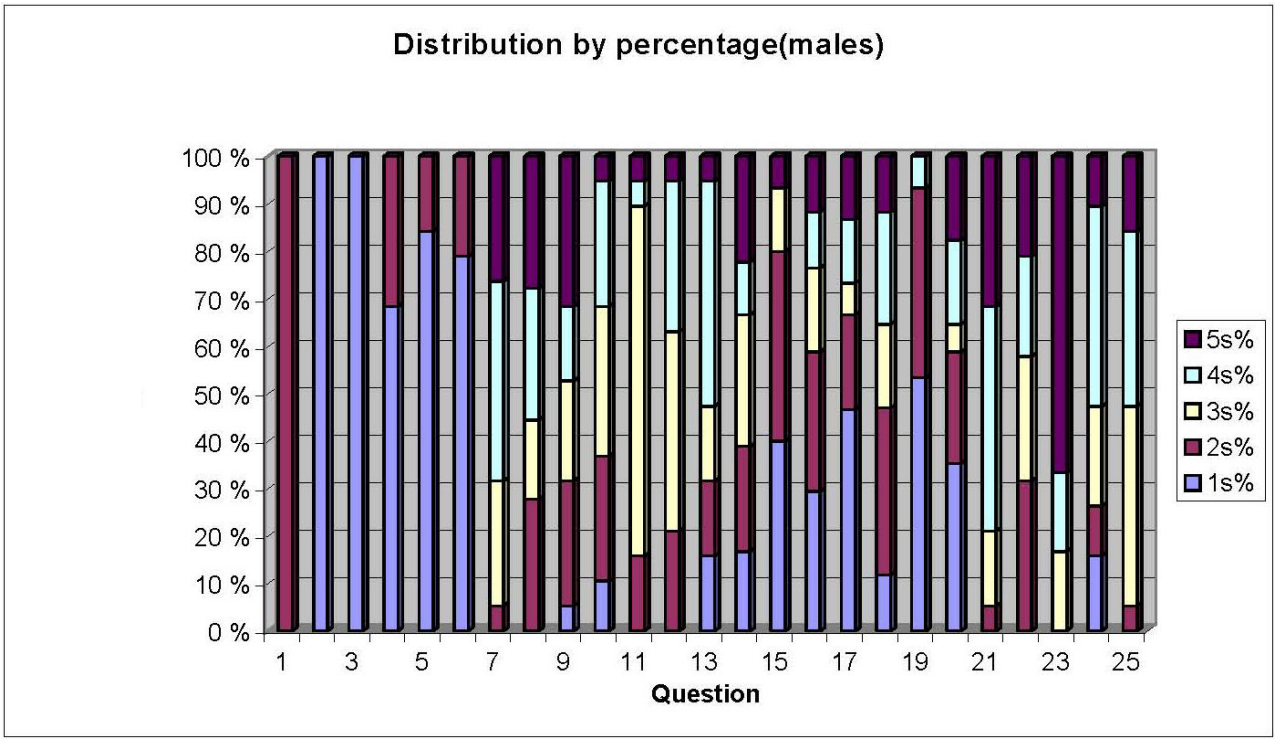


Figure 7: Initial questionnaire for males

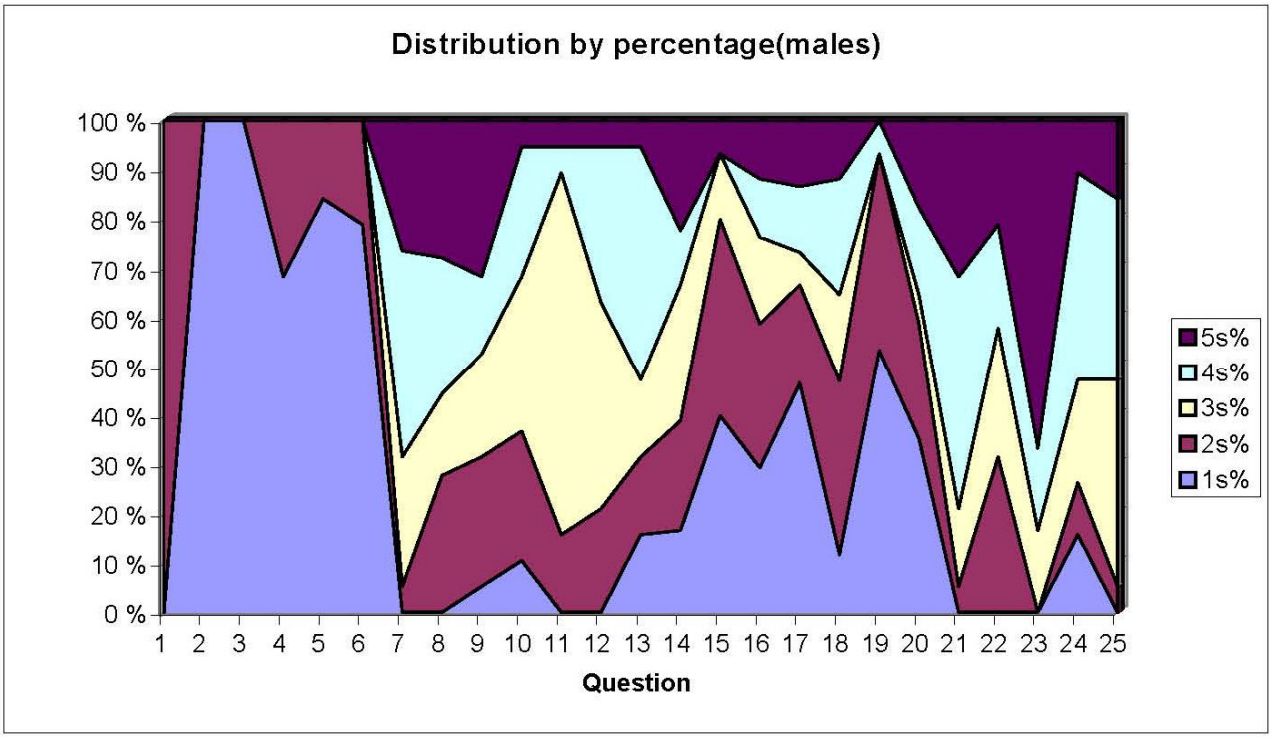


Figure 8: Initial questionnaire for males

Results for females

Females seem to be less occupied with playing games and using the PC for entertainment, and only a few seems to be playing online-games. As we can tell from the range of questions from 14 through 21 the trend is quite negative when it comes to playing games. The emphasis on playability and graphics is something that stands out. The explanation can very well be the fact that females are not as preoccupied with competition as males, as we can tell from the question number 9.

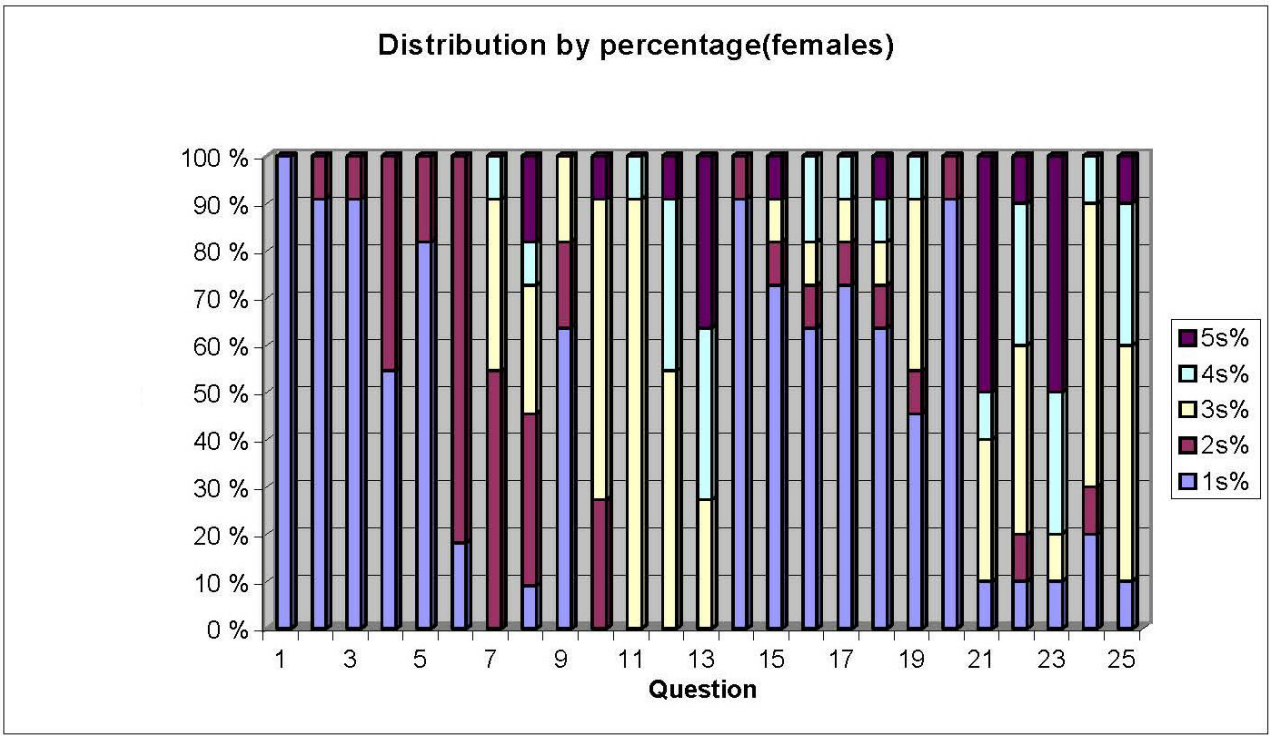


Figure 9: Initial questionnaire for females

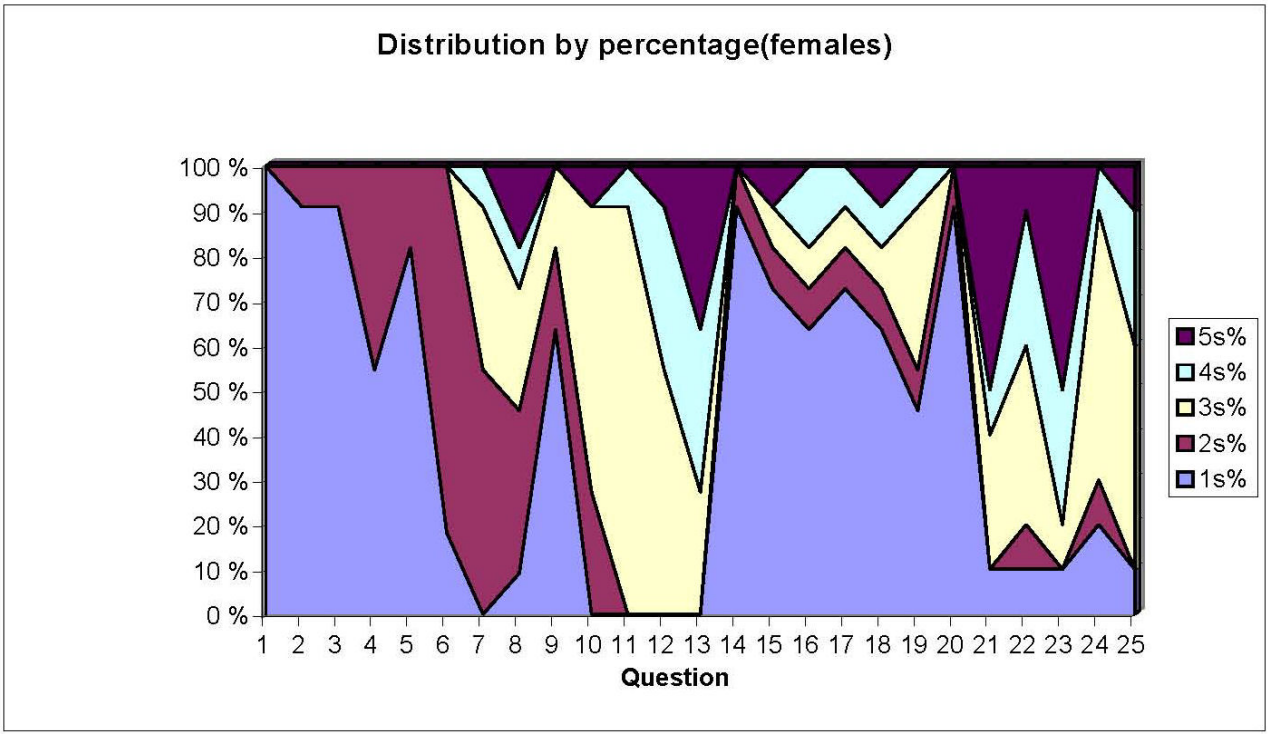


Figure 10: Initial questionnaire for females

5.1.2 Results for females versus males

By looking at differences between males and females we see several interesting features. The most interesting feature is the difference in competitiveness and the interest for playing competitive games. The difference in the amount of general gameplay is also an interesting fact. We can safely conclude that females play less and are generally less interested in playing games.

5.2 Results from pre-game questions

Before playing the users had to answer a few questions. The results we hoped would reflect each player's performance and progress. But as we only were able to let them play for an hour some of the results may be inconclusive.

Color	Q1	Q2	Q3	Q4
Cyan	0	0	3	4
MidnightBlue	1	0	2	2
Cyan	1	4	1	1
Blue	1	0	3	4
Cyan	0	1	2	2
Blue	1	0	3	3
Purple	1	0	1	1
Honeydew	1	0	2	2
Cyan	1	0	3	3
Green	1	2	2	4
Blue	0	1	2	3
Green	1	0	2	2
Honeydew	1	1	2	4
Cyan	0	2	2	4
Blue	1	0	2	3
Red	1	0	2	2
Blue	1	0	3	3
Red	1	0	2	2
Cyan	1	0	4	4
Yellow	1	0	4	2
Cyan	1	0	0	0
Cyan	0	0	3	3
Cyan	1	4	4	3

Table 8: Pre-game questions

5.2.1 Results for all

	Kjønn?	Hvor mye tid bruker du ukentlig på matte(utenom ordinær undervisning)?	Hvor flink er du i matte?	Liker du matematikk?
0s	jente	0-1 time	Lite flink	Svært lite
	5	16	1	1
	21,7 %	69,6 %	4,3 %	4,3 %
1s	gutt	1-2 timer	Under gjennomsnittet	Lite
	18	3	2	2
	78,3 %	13,0 %	8,7 %	8,7 %
2s		2-3 timer	Gjennomsnittlig	Passe
		2	11	7
		8,7 %	47,8 %	30,4 %
3s		3-5 timer	Over gjennomsnittet	Litt gøy
		0	6	7
		0,0 %	26,1 %	30,4 %
4s		over 5 timer	Dyktig	Liker veldig godt
		2	3	6
		8,7 %	13,0 %	26,1 %

Figure 11: Results for pre-game questions

The amount of time spent on math per week spanned from approximately one hour to more than 5 hours. Most people (70%) spend less than an hour per week on math, and 13 % spend between 1 and two hours per week. Almost 9% spend more than 5 hours per week working with math, which is a lot of time spent on one subject.

Almost 50% consider themselves of average proficiency when it comes to math, and more than 26% consider themselves above average.

Most people enjoy math, 26% enjoy it very much. 30% likes it more than average, and another 30% thinks nothing special of math.

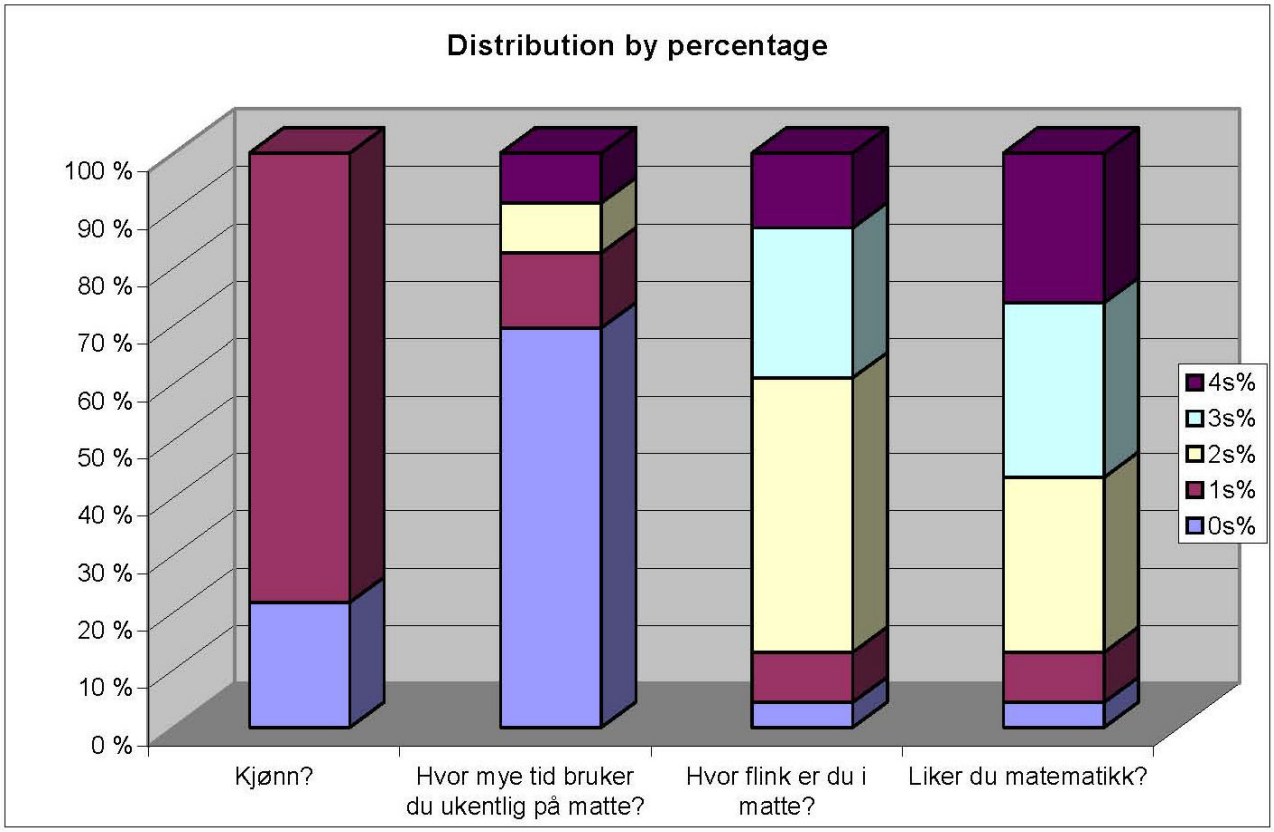


Figure 12: Results for pre-game questions

5.2.2 Results for girls

	Kjønn?	Hvor mye tid bruker du ukentlig på matte(utenom ordinær undervisning)?	Hvor flink er du i matte?	Liker du matematikk?
0s	jente	0-1 time	Lite flink	Svært lite
	5	2	0	0
	100,0 %	40,0 %	0,0 %	0,0 %
1s	gutt	1-2 timer	Under gjennomsnittet	Lite
	0	2	0	0
	0,0 %	40,0 %	0,0 %	0,0 %
2s		2-3 timer	Gjennomsnittlig	Passe
		1	3	1
		20,0 %	60,0 %	20,0 %
3s		3-5 timer	Over gjennomsnittet	Litt gøy
		0	2	2
		0,0 %	40,0 %	40,0 %
4s		over 5 timer	Dyktig	Liker veldig godt
		0	0	2
		0,0 %	0,0 %	40,0 %

Table 9: Results for pre-game questions for females

By looking at the graphical representation below we clearly see that the females consider themselves average or above average in math proficiency. They also spend considerably more time working with math than males. And the seem to like math better than males.

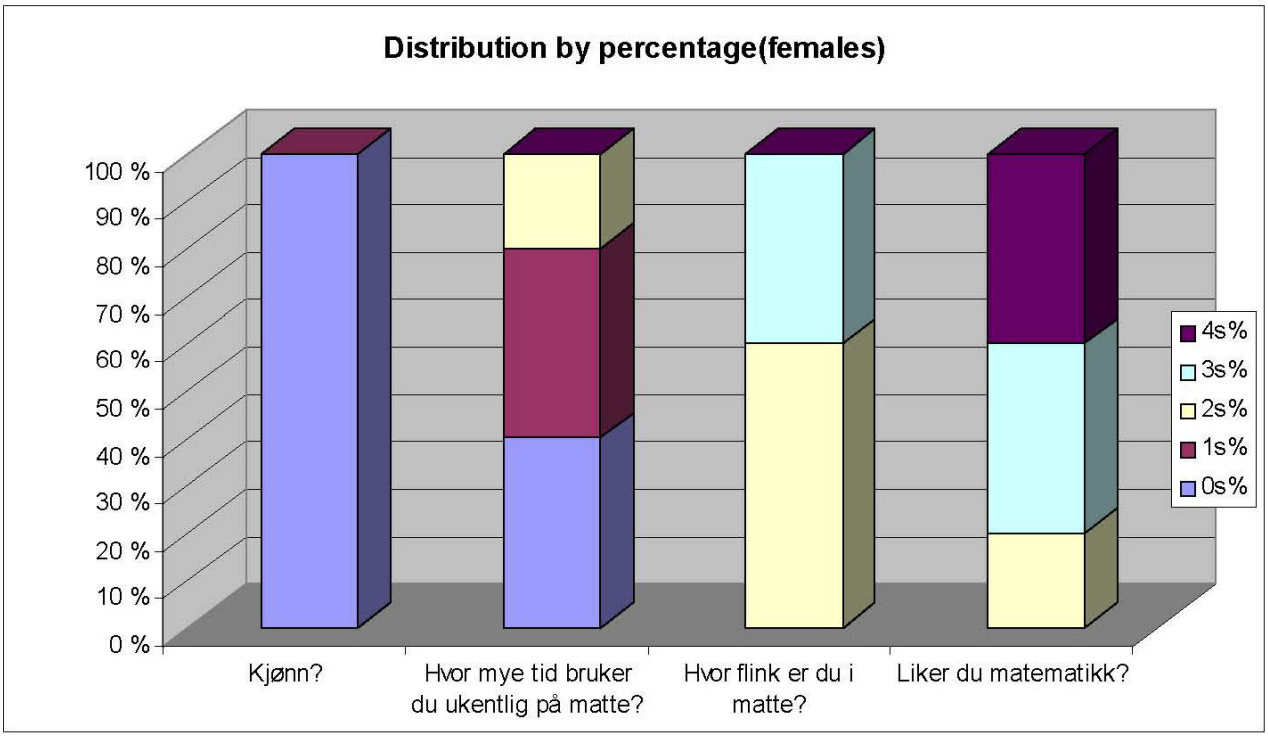


Figure 13: Results from pre-game questions for females

5.2.3 Results for boys

	Kjønn?	Hvor mye tid bruker du ukentlig på matte(utenom ordinær undervisning)?	Hvor flink er du i matte?	Liker du matematikk?
0s	jente	0-1 time	Lite flink	Svært lite
	0	14	1	1
	0,0 %	77,8 %	5,6 %	5,6 %
1s	gutt	1-2 timer	Under gjennomsnittet	Lite
	18	1	2	2
	100,0 %	5,6 %	11,1 %	11,1 %
2s		2-3 timer	Gjennomsnittlig	Passe
		1	8	6
		5,6 %	44,4 %	33,3 %
3s		3-5 timer	Over gjennomsnittet	Litt gøy
		0	4	5
		0,0 %	22,2 %	27,8 %
4s		over 5 timer	Dyktig	Liker veldig godt
		2	3	4
		11,1 %	16,7 %	22,2 %

Table 10: Results for pre-game questions for males

Most males spend less than an hour a week working with math. Some also considers themself less proficient in math than average. And we see that some doesn't enjoy math that much either.

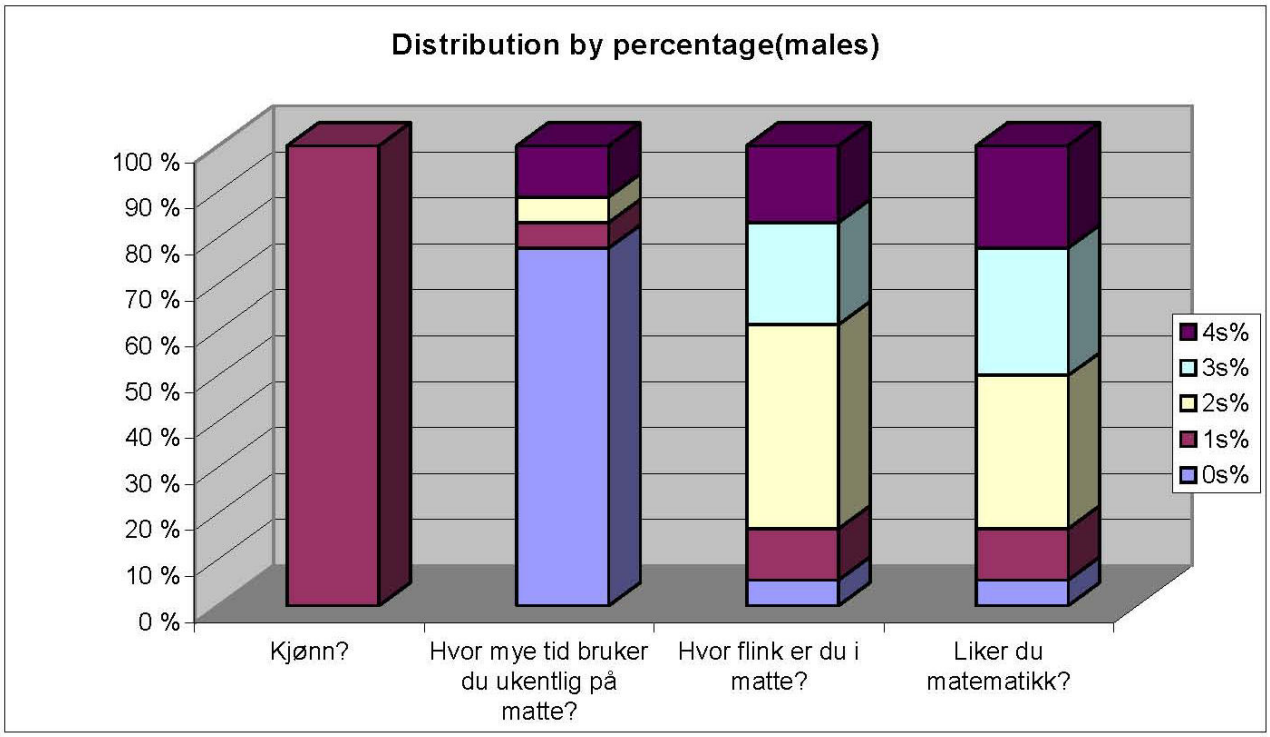


Figure 14: Results for pre-game questions for males

5.3 Results from final questionnaire

Many of the questions in the final questionnaire needed to be approached by looking at and evaluating comments from the users. Thus there isn't as much data to analyze as in the previous questionnaires. The fact that the class that didn't play the game scored much higher on the test, can pretty much be explained by the time the test was taken. The first class played the game and took the test when they began working on the subject, while the second class took the test 2 weeks later.

		Kjønn?	Hvor mye tid bruker du ukentlig på matte?	Hvor flink er du i matte?	Liker du matematikk?	Kjønn	Hvor mange timer bruker du på matematikklekser ukentlig?	Hvor flink er du i matte?	Hvor godt liker du matematikk?	Hvor mye nytte tror du at du kunne ha av spill som læremiddel?	Hva er ditt nivå når det gjelder sannsynlighetsregning og kombinatorikk?	Correct	%Correct
Class 1	Have played the game	Q1	Q2	Q3	Q4	2,1	2,2	2,3	2,4	3,1	3,2		
		0	0	3	4					3	3	4	40,0 %
		1	0	2	2					x	x	3	30,0 %
		1	4	1	1					3	2	4	40,0 %
		1	0	3	4								0,0 %
		0	1	2	2								0,0 %
		1	0	3	3								0,0 %
		1	0	1	1					x	x	3	30,0 %
		1	0	2	2					2	3	2	20,0 %
		1	0	3	3					3	2	2	20,0 %
		1	2	2	4					3	3	4	40,0 %
		0	1	2	3					3	3	0	0,0 %
		1	0	2	2					3	3	5	50,0 %
		1	1	2	4					3	2	3	30,0 %
		0	2	2	4					4	3	7	70,0 %
		1	0	2	3					3	2	3	30,0 %
		1	0	2	2					3	2	4	40,0 %
		1	0	3	3					2	3	2	20,0 %
		1	0	2	2					3	3	8	80,0 %
		1	0	4	4								0,0 %
		1	0	4	2								0,0 %
		1	0	0	0								0,0 %
		0	0	3	3								0,0 %
		1	4	4	3								0,0 %
	Haven't played the game					2	1	4	3	3	2	1	10,0 %
						1	2	5	5	4	2	4	40,0 %
						1	3	4	5	3	3	1	10,0 %
Class 2						1	1	4	4	4	3	2	20,0 %
						1	1	4	3	3	4	5	50,0 %
						1	3	4	3	3	3	7	70,0 %
						1	2	3	4	4	2	5	50,0 %
						2	1	2	2	3	2	3	30,0 %
						2	2	5	5	5	4	4	40,0 %
						1	2	5	5	3	3	7	70,0 %
						1	2	5	4	4	4	7	70,0 %

Table 11: Final Questionnaire

A common denominator is that most people think that game based education is useful. Because the students were only allowed to play for an hour, the results from the test conducted afterward may not be conclusive. The first class has an average score of 36%, while the second class has an average score of 42%.

Some of the main differences between the classes are that the first class is larger, and consists of 78% males. The second class is small, and consists of only 27% males.

average	question
0,78	kjønn
0,65	Hvor mange timer bruker du på matematikklekser ukentlig?
2,35	Hvor flink er du i matte?
2,65	Hvor godt liker du matematikk?
2,92	Hvor mye nytte tror du at du kunne ha av spill som læremiddel?
2,62	Hva er ditt nivå når det gjelder sannsynlighetsregning og kombinatorikk?
3,60	Correct

Table 12: PostGame Questionnaire for Class 1

As we look at the differences between the classes we see that the second class spend more time on math, considers themselves more proficient in math and likes math better. Considering the differences mentioned above, it's not all that surprising that the average score is higher too.

average	question
1,27	kjønn
1,82	Hvor mange timer bruker du på matematikklekser ukentlig?
4,09	Hvor flink er du i matte?
3,91	Hvor godt liker du matematikk?
3,55	Hvor mye nytte tror du at du kunne ha av spill som læremiddel?
2,91	Hva er ditt nivå når det gjelder sannsynlighetsregning og kombinatorikk?
4,18	Correct

Table 13: PostGame Questionnaire for Class 2

5.3.1 Student evaluation of the prototype

The students were given the opportunity to evaluate the game prototype by giving positive and negative feedback as well as suggestions for improvements. The students were also asked in what context they believe educational games are most suitable for. The following section sums up the answers provided.

5.3.1.1 Positive feedback

- A nice break from the regular teaching
- A different view to the mathematic topics at hand
- Good user interface, easy to use
- Interesting approach
- Perspicuous
- Challenging

- Helps memorizing formulas by using them
- Level of difficulty

5.3.1.2 Negative feedback

- Bad graphics
- Level of difficulty, too hard
- Not 100% coherent with what they had been going through in class
- Limited number of exercises
- The possibility of guessing may be abused

The level of difficulty was given as both positive and negative feedback by different students. The majority of the students found the difficulty level of the exercises adequate. This reflects that the level of competence vary from student to student, and may suggest that the game prototype did not appear as helpful to the less proficient students.

5.3.1.3 Suggestions

- Better graphics
- Animations
- Sounds
- More and different types of games
- Practical assignments
- Animated solutions
- More of a story-line and atmosphere

Most of the suggestions for improvement call for more and better multi media effects. This is consistent with the results from the initial questionnaire.

5.3.1.4 In what context they believe educational games could be used for

- Repetition
- Solving exercises
- Not suitable for teaching new topics

6 Proposed solution

The following section describes the prototype and the development tools applied.

6.1 Development tools

The game has been created using Microsoft Visual Studio .Net C#. GDI+ serves as graphical library.

6.1.1 Microsoft Visual Studio .Net C#

.Net and C# was released by Microsoft to the ECMA standards group in 2000 as an answer to the changing market of computer applications. Over the last years there has been a growth in the light weight web application domain, where the end user communicates with the business application through a web interface. As an improvement to Visual Studio version 6.0, .Net (or 7.0) provides integrated solutions to creating such applications in an efficient way.

C# offers a programming syntax that has the flexibility of C/C++, yet it provides the simplicity of JAVA by adding transparency of the most common programming pitfalls such as memory handling, threading and static linking.

C# programs require far less system resources that an equivalent JAVA application, yet still manages to come near C/C++ when it comes to performance, only trailing behind due to the overhead related to the memory and thread handling transparency. [25]

6.1.2 GDI+

The Microsoft Windows Graphics Device Interface (GDI) enables applications to use graphics and formatted text on both the video display and the printer. Windows-based applications do not access the graphics hardware directly. Instead, GDI interacts with device drivers on behalf of applications [26].

GDI+ is well integrated in Visual Studio .Net and is suitable to use with raster graphics. It provides functionality to draw the most common geometrical shapes, formatted texts and supports a variety of image file formats. More powerful graphic libraries such and DirectX exists, but these may be considered too much for this project.

6.1.3 Documentation

The C# compiler offers to generate code documentation in XML format. This is effectuated by using the "/doc filename.xml" compiler directive or by entering a file name in the project properties dialog as shown in figure 15.

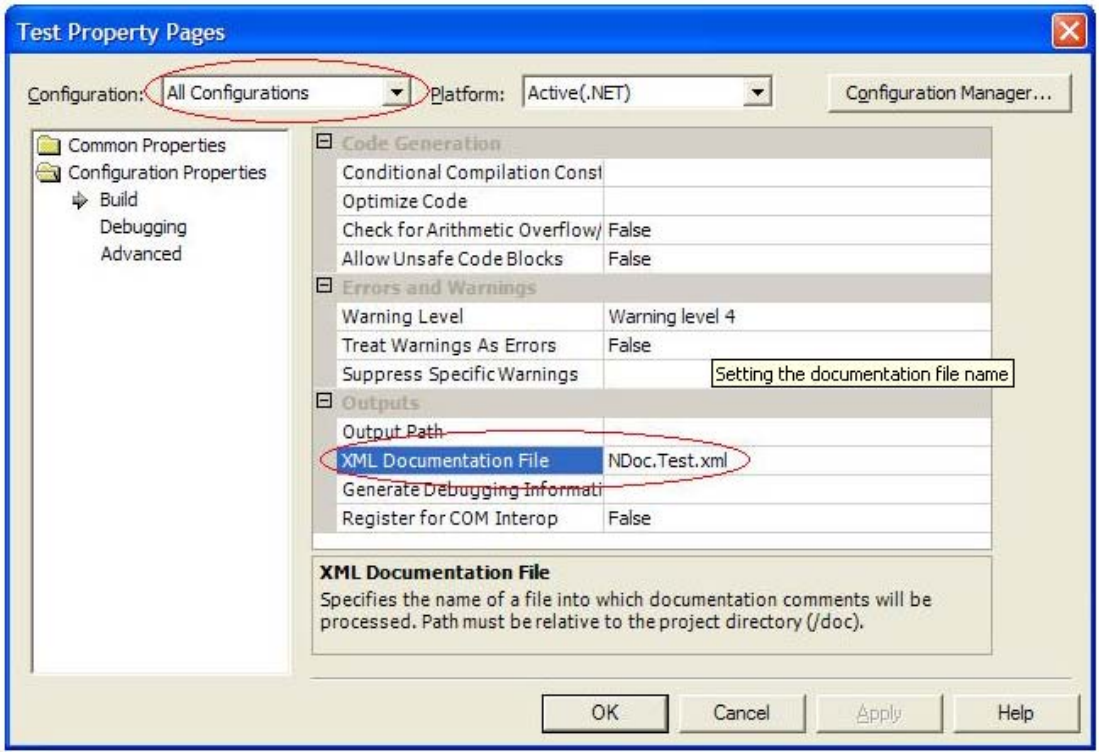


Figure 15: Visual Studio build configuration

The XML documentation is independent from presentation, and by using cascading style sheets (CSS) the documentation may be viewed in any desirable way.

Visual Studio inserts an appropriate XML documentation tag into the code by typing three consecutive slashes "///"; hence this is an efficient way to document the code. In

addition to creating XML documentation these comments are available through the intellisense system, providing the programmer with instant help while coding. [27]

NDoc is an open source project available through SourceForge that creates readable documentation from the XML-documentation files. NDoc has been used to generate MSDN like documentation for this project. [28]

6.1.4 Exercise portability

All textual exercises for the games are stored on XML-files. There are many factors that speak in favor of storing the exercises independently from the executable program code. The ability to add or edit exercises without having to recompile speaks for itself. Although it has not been a priority for this project, using XML-files for this purpose also opens for the possibility to store the exercises on the game server. In this way new sets of exercises may be published without requiring maintenance work locally, with the benefits of increasing the maintenance quality factor as it is not necessary to reinstall or update the program files. Another benefit is the possibility to keep different sets of exercises for different schools and classes. In this way the exercises may be tailored locally by the teacher and perfectly adapted to students at different levels.

XML has become a format that most computer engineers are familiar with, and Visual Studio .Net supports XML-files through a class library that makes it easy for the developers to parse XML files. [29]

6.2 Introduction to the prototype

The main part of this master thesis has been to design and create educational computer games. Rather than putting all the chips on one horse, we have designed a module based game learning platform that may offer a number of games. The prototype of the game contains three playable game modules. The different modules have been created with diversity in mind, with each module emphasizing different approaches to math learning. All three modules will be explained in detail in their own sections.

Accordingly to the 2MX educational plan active learning has been prioritized with the focus of solving exercises. The games intend to motivate the students to do exercises and to "force" them to do it the correct way in order to proceed. The game does not intend to replace the Sinus text book, on the contrary we advice to use the text book actively while playing.

The Venn diagram game is created as a questionnaire, where the player is presented an object and three conjunctive answer sets. The student is to select the sets or subsets that are true for the object. 2MX offers the students an introduction to set concepts and Venn diagram. This games offers to build understanding of set theory and Venn diagrams by connecting simple objects with set theory.

The card game lets the player play 21 against the computer. To succeed in this game the player must count the cards played and calculate the probability of coming close to 21 points and make the decision whether to risk drawing a new card or not.

The third module is basically a new approach to multiple choice examinations. Given an exercise and a pool of possible answers the player must find the correct answer for a given problem. Rather than just providing the answer of the exercise, the student will have to identify what method to use, what formula to use, what numbers to use with the formula and the numerical answer. Another difference from a multiple choice paper is

that the student must find all the correct answers before moving on to the next exercise. In this version the game is limited to exercises within counting combinations.

6.3 The game server

The game server is responsible for keeping track of all the users. While a student plays the games, all relevant moves and results are stored in the game database. The stored data are used to restore the game at last known status when a player logs on. Independently of which computer is used to play the game, the student may continue where he or she left off. In this way any student may easily play the game both at school and at home without having to start over again.

Another benefit of having a game server is the contingency of analyzing the result. The teachers may use statistics generated from the game database to evaluate the proficiency of their classes and use that information to adjust the tuition style and content. The evaluation data may also be used to assess the quality of each game module and each exercise provided with the game modules with concern of making improvements.

6.4 Game modules

This section describes the different game modules the solution is built on.

6.4.1 Game world module

6.4.1.1 Purpose

This module works as a main menu where the player selects which game to play. To enhance the feeling of playing a game this main menu has a graphical representation where the player has to move his or hers character interactively by using the arrow keys.

6.4.1.2 Introduction

This module offers an orthographic view of the game world that is built from tiles. A tile is a small image that when placed adjacent to other tiles, creates an image. Each tile has a

practicability property. The character can only move onto tiles that are passable. This feature is used on the edges of the map and on obstacles, such as rocks and pounds, which are placed randomly in the map.

6.4.1.3 User Interface

The character may be moved by using the arrow keys. The character will only move if the next tile is passable, that is if it is not blocked by any objects or is not at the edge of the view.

When positioned above a module icon, the module may be entered by hitting the “Enter”-key.

A help dialog is available by clicking on the yellow question mark at the upper right corner of the window. This dialog explains the user interface of this module and provides access to viewing the high scores, returning to the game and to quitting the game.

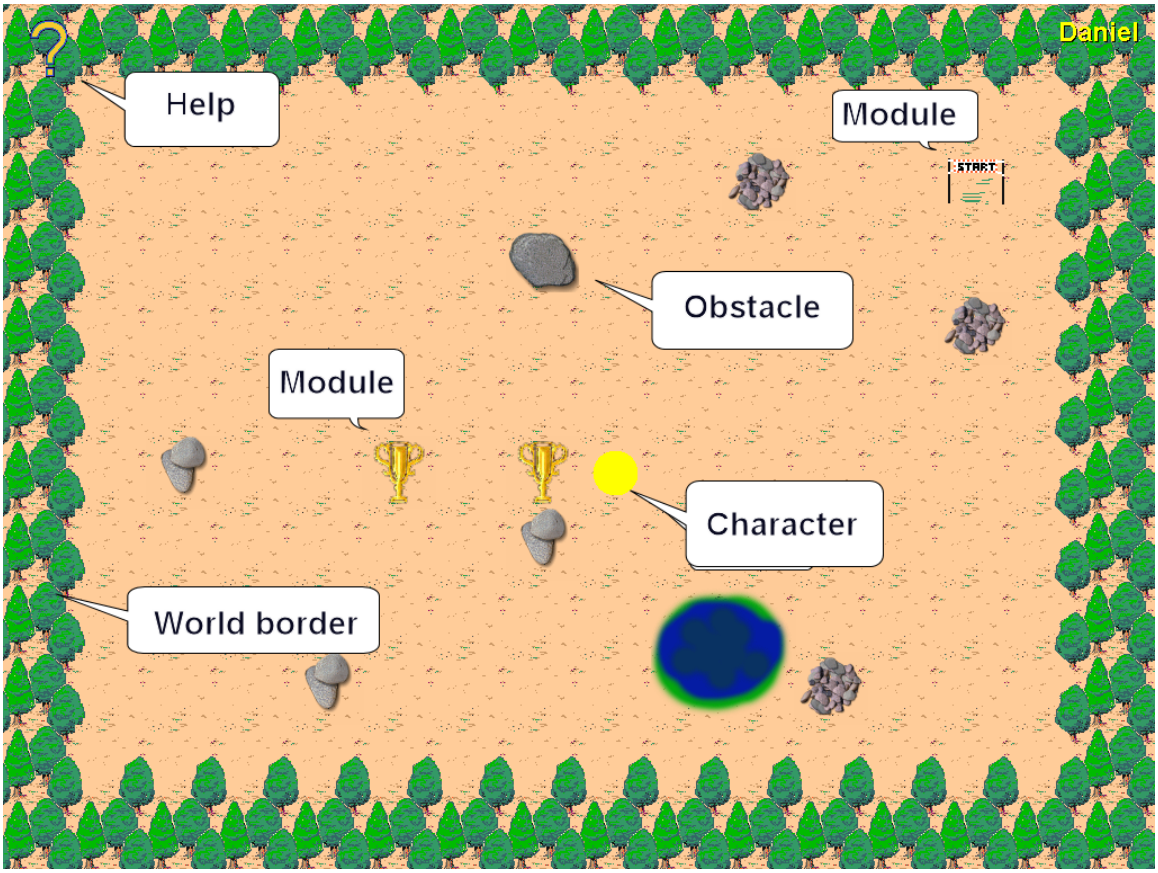


Figure 16: Main menu user interface

6.4.2 Venn diagram module

6.4.2.1 Purpose

This game intends to build understanding of set theory and the use of Venn diagram in set theory.

6.4.2.2 Introduction

Venn diagrams was invented by John Venn (1843-1923), originally intended to help performing psychological analyses. However, simple set theory, with three sets or lesser, can elegantly be illustrated by using Venn diagrams. The Venn diagram is made up of two or more overlapping circles that in mathematics show the relationship between sets. The areas that are limited by the intercepting circle outlines form subsets. In figure 17, there are 8 subsets with the Universe included. [30]

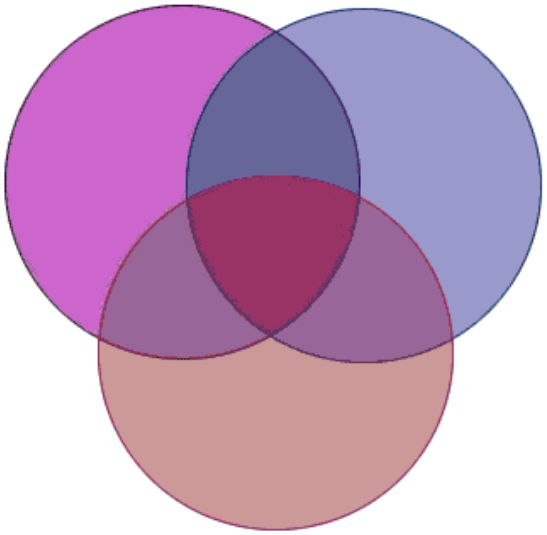


Figure 17: The basic 3-set Venn diagram

6.4.2.3 Game concept

The game is based on an interactive Venn diagram where the player can select any subset, including the universe itself. Each set is given content and the player is to select the subset(s) which match the exercise text. Further the game can contain any number of levels where the difficulty is increasing for each level. This prototype has five levels. Each level may contain ten or more exercises, preferably 15 or more. The requirement to advance to the next level is to answer the 10 first exercises correctly. If failing to do so, the level is restarted when all exercises are attempted.

The first level has the purpose of introducing the user to the game and to build general understanding of how to use Venn diagrams in set theory. It uses concepts from our daily lives that most are familiar with. To keep it simple the answers are limited to only one subset.

At level two it is still kept quite simple, but instead of concepts from our daily lives fundamental concepts from mathematics are used.

At level three, mathematical questions that require knowledge of the curriculum of 2MX are asked. Some exercises may even require a calculator present.

At level four, set theory algebra is introduced. The player may be required to select any number of subsets.

At level five, more complex set theory algebra is introduced.

6.4.2.4 User interface

The game is fully mouse controlled. Any set is selected or deselected by clicking inside it with the left mouse button. The answer is checked by clicking on the button labeled "Sjekk svar". "Instruksjoner" shows a dialog with instructions. "Avslutt" exits the game and returns to the main menu game.

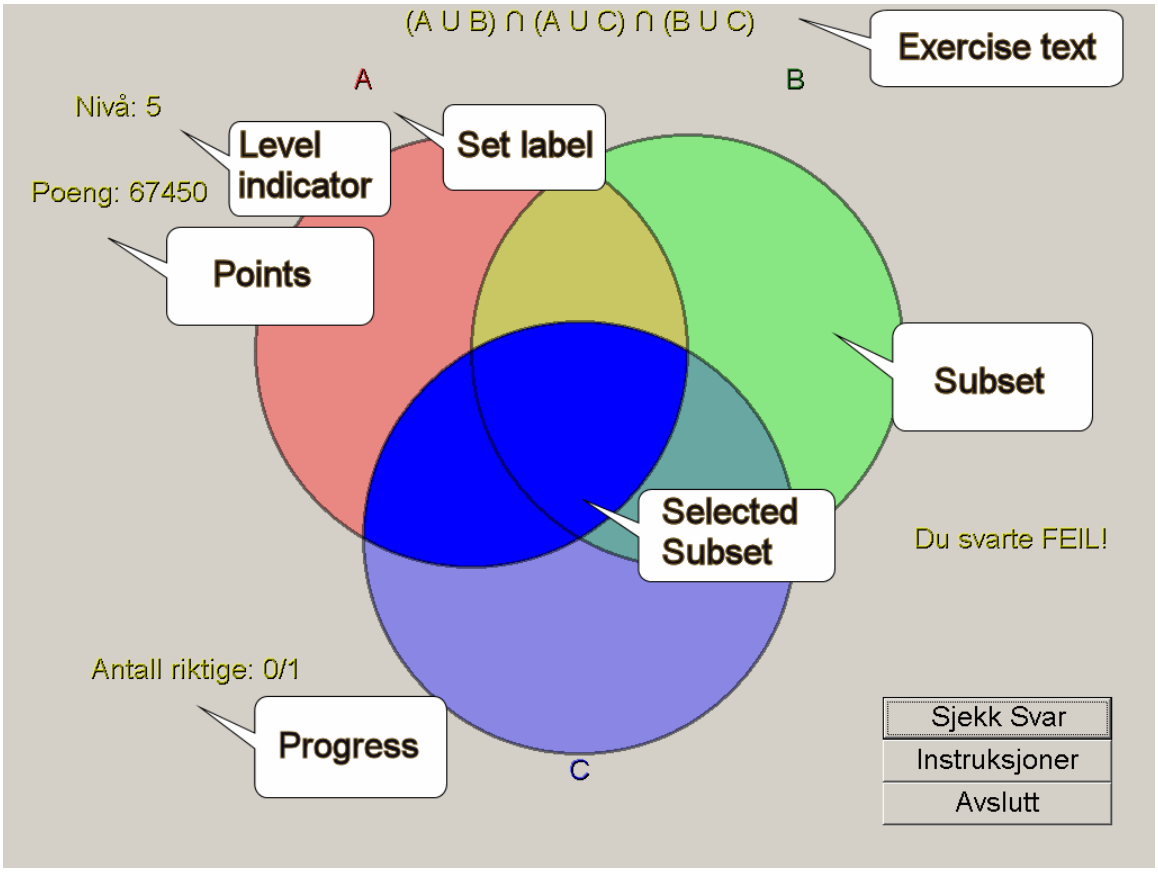


Figure 18: Venn diagram game user interface

6.4.3 Maze game module

6.4.3.1 Purpose

The student is to read and understand a textual problem and then to identify the correct method and to apply the appropriate formula, calculations and answer.

6.4.3.2 Introduction

In the field of combinatorial mathematics, many of the assignments spring directly from problems in our daily lives. Given a number of options, in how many ways may these options be combined depending on whether order is relevant and/or repetitions are allowed? If order is irrelevant, the two texts “ABC” and “CBA” are equivalent, typically resulting in less combinations. When repetitions are allowed, an element from a set is reused, typically resulting in more combinations. An example of this is a bank account number, where any digit may be any number from 0 to 9. With eleven digits, assuming there are no other restrictions, there are 10^{11} possible bank accounts.

Four basic methods, figure 19, are used in the curriculum of 2MX to count the number of combinations available. These are permutations, arrangements, combinations and factorials. Permutations and factorials are the same kind of selection, where with factorials you select all items from a set and with permutations you select from 1 to n items from the set.

Order is relevant	Repetitions are allowed	Method	Formula
Yes	Yes	Arrangement	n^k
Yes	No	Factorial	$n! = 1*2*3*...*n$
Yes	No	Permutations	$P(n,k) = \frac{n!}{(n-k)!}$
No	No	Combinations	$C(n,k) = \binom{n}{k}$

Figure 19: Formula sheet

Such mathematical problems are typically presented to a student by a textual exercise. The student is then to determine if the order is relevant and if repetitions are allowed. The two yes and or no questions will determine the type of method to be used. Once the method is decided upon, the appropriate numbers must be put into the formula and the answer calculated by using a calculator.

6.4.3.3 Game concept

To represent the typical textual combinatorial exercises a maze-like game was designed. The game consists of a set of locations, where each location has an exercise that must be solved before moving on. The game itself is basically a background image with foreground objects. The background image has the purpose of adding a plot and atmosphere to the game. It may give the illusion of moving “forward” in a world by making progress. The foregrounds images may be used to enhance this illusion by adding variation to the scene.

The centre of this game is the educational value. A bare minimum of distractions from solving mathematical problems is to be present. It is important that the user of the game never is in doubt whether they play the game wrongfully or if they solve the mathematical exercises wrongfully. This implies a very simple game plot and controls that everyone with just a little computer experience should be able to master. Based on previously performed research on this area, drag and drop is the preferred option [31]. If

the player is to type in the answer, uncertainty relying in questions of text formatting, required number of decimals and so forth may make the student insecure in their skills.

Drag and drop is based on the concept where a pool of answer alternatives floats on the screen and the player is to move these alternatives into a reserved area on the screen by using the mouse. An obvious drawback here is the opportunity to systematically test the solution alternatives in order to find the correct one by guessing. On the other hand the guessing option is available for students who are stuck and need some help to get along. A way of restricting the motivations behind guessing is also to only allow one answer per answer box at one time. When attempting to drag more then one answer alternative into a box the result is never approved, even if the correct answer is within the box. The exercises to be found in this game are relatively hard and there are multiple exercises using the same method. The student may use the guessing method at an early exercises, then to use the thinking method at a later exercise and then to realize the connection between the exercises and their respective solving methods.

The exercise to be solved consists of a textual exercise, up to four “answer boxes” and a pool of solution alternatives. These answer boxes correspond to a “Method-box”, “Formula-box”, “Calculations-box” and “Answer-box” (Figure 20).

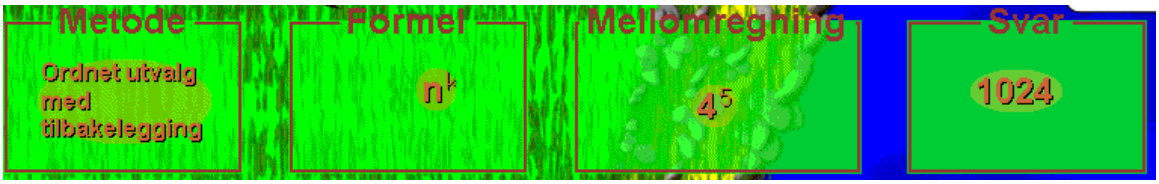


Figure 20: Answer boxes

One solution alternative from each category is to be dragged into the correct box for the assignment to be approved. Once the assignment is approved the player may move forward to unexplored territory. The answer boxes give instant feedback to the student. A green background color indicates that the answer is correct and a red one indicates that it is not correct. When all boxes are green the exercise is solved.

The level of difficulty may be adjusted by requiring that all the answer boxes must have the correct solution alternative inside in order to become green. This all or nothing approach may be confusing for young students as a correct alternative will not give positive response unless all the other alternatives are correct as well. As the target group of students is relatively new to combinatorial mathematics, it is assumed that individual feedback for each answer box helps develop understanding of all the steps required from reading and understanding the exercise, selecting the correct method and to using the formula to get the correct answer. If a student is stuck and not sure what type of method to use, help may be achieved by guessing. Hopefully the results from guessing will help the student select the correct formula and numbers to use to get to the answer.

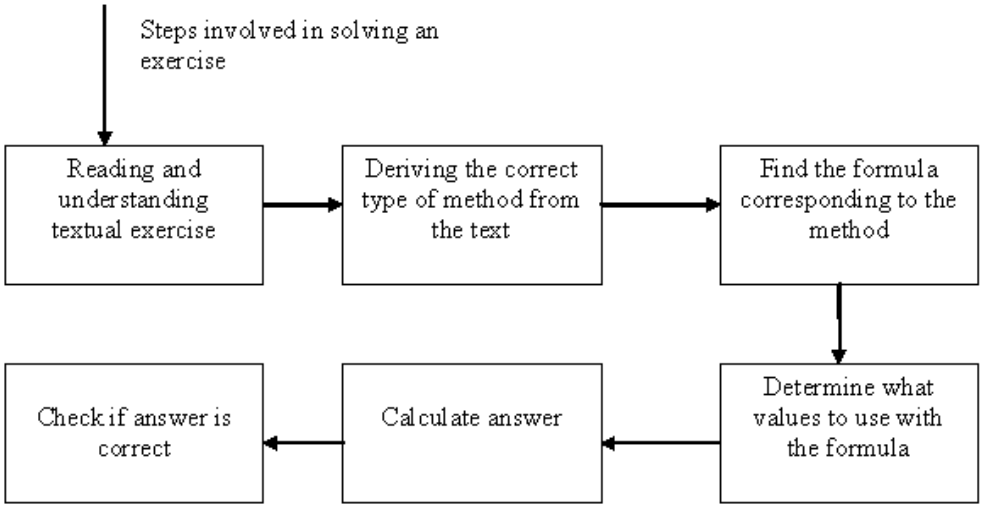


Figure 21: Process of solving an exercise

The game has to be completed within a given amount of time. A clock counting down is displayed at the left top of the screen. The main purpose of the clock is not to stress out the students, but to motivate students who have completed the game to play it again for a better score. In this way the exercises are repeated which is an essential step in gaining understanding of a problem. Students who do not manage to finish the game on time, are forced to start over again. In this way they will have to redo the simpler exercises, which they assumingly did not understand in the first place, helping them to understand the relations between the problem and the correct approach to solving it.

6.4.3.4 User interface

Available objects are the menu button overview map, clock, exercise text, answer areas, solution alternatives, the check answer button and navigation buttons.

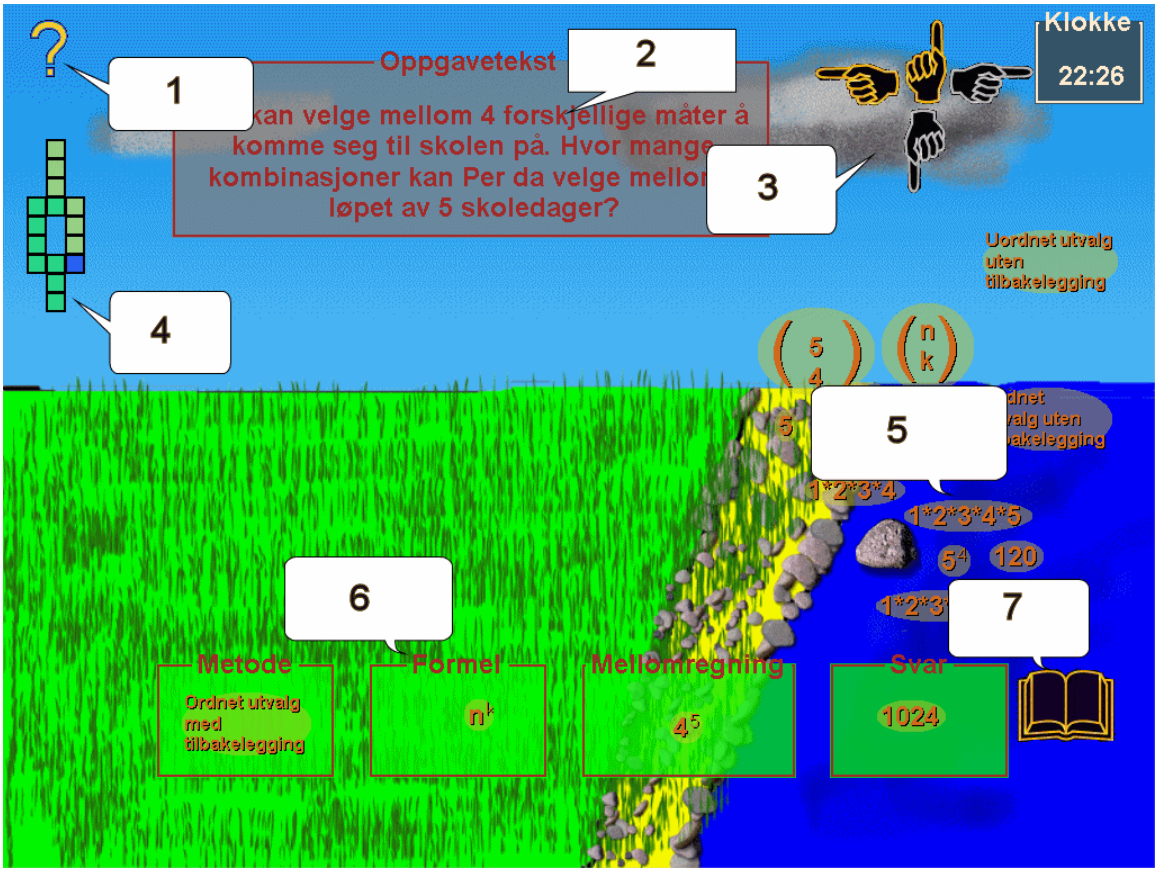


Figure 22: User interface

1) Help button
2) Exercise text box
3) Navigation buttons
4) Map of scene. Yellow indicates unsolved, green solved and blue marks the locations you are at.
5) Pool of solution alternatives
6) Answer boxes. Green indicates correct answer, red incorrect answer.
7) Check answer button.

The game is fully mouse controlled. It is possible to drag and drop the solution alternatives and to click on the available buttons. To avoid confusion, a tooltip with an explanatory text is displayed when the mouse is hovered over a foreground object. The navigation buttons are disabled, or grayed out, when the corresponding location is unavailable.

A help dialog is available by clicking on the yellow question mark at the right top of the screen.

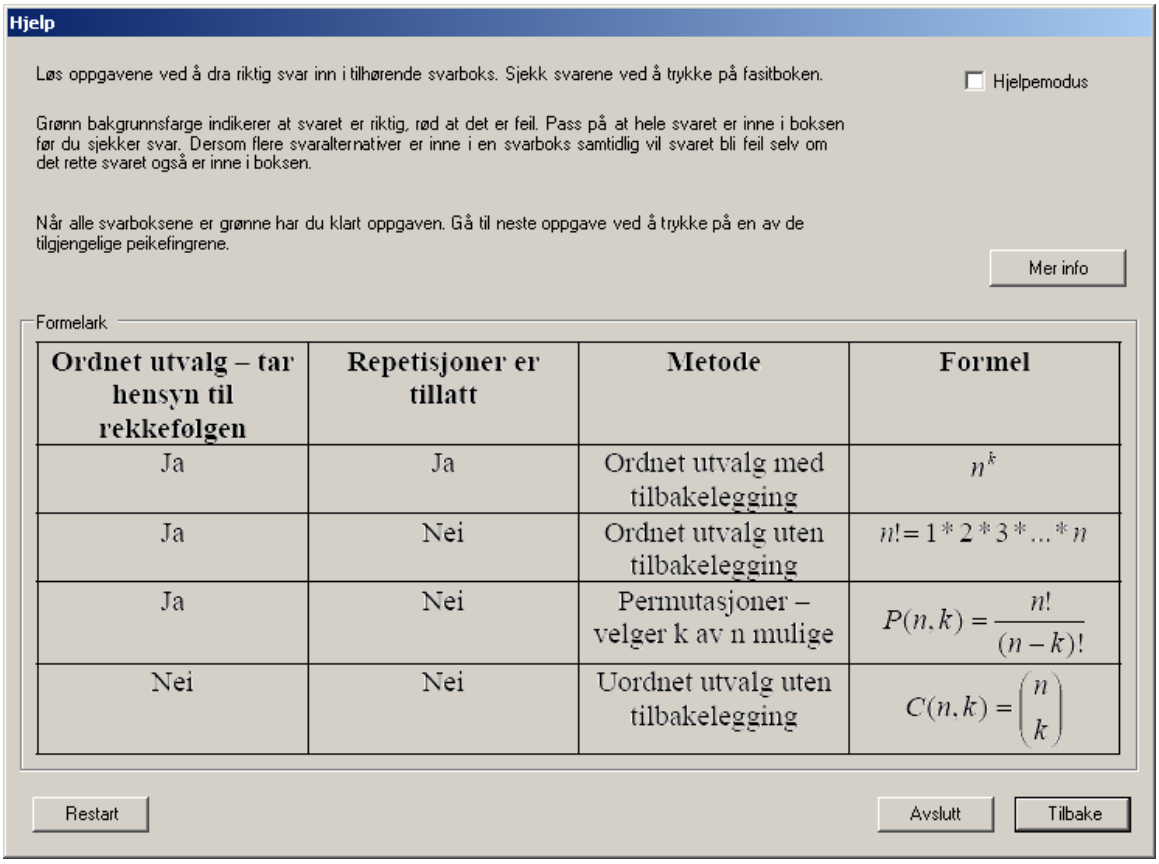


Figure 23: Help dialog

This help dialog explains the basic concepts of the game and displays a formula sheet.

The help dialog also provides other functionality such as restarting the game, quitting the game and returning to the game itself. If the Help Mode “Hjelpemodus” checkbutton is checked, a tooltip is displayed when hovering the mouse over a solution alternative. The

tooltip's text indicated whether the solution alternative belongs in the method, formula, calculations or answer area.

6.4.4 Casino module

6.4.4.1 Purpose

The students are to take practical advantage of probability calculations in finding the best moves in order to successfully play the card game of 21.

6.4.4.2 Introduction

21 or Blackjack (Blackjack is used for a different card game in Britain) was originating from French casinos around 1700 A.D.

The objective of 21 is to get as close to or preferably exactly 21 points. If exceeding 21 points the player loses. If none of the players have exactly 21 points, the player that is closest to 21 points wins. The numerical values of the cards are 10 for knight, queen and king, 1 or 11 for aces and face value for the other cards.

The first recognized attempt to apply mathematics to 21 began in the early 1950s. Roger Baldwin wrote an article in the "Journal of the American Statistical Association" titled "The Optimum Strategy in Blackjack". The strategy was mathematically proved with the laws of probability and statistics. These strategies were under constant improvement until Julian Braun who used IBM mainframe computers in 1977 to run Blackjack simulations, developed what is considered the final counting techniques for the game of 21. Ken Uston, who used computers to calculate his moves, won over $100.000 dollars in a very short time. He was accused of cheating, but was acquitted since the computers only used public information from the actual games.

The history of 21 shows that there is a direct connection between calculating probability and succeeding in the game. [32]

6.4.4.3 Game Concept

In this game the student plays one on one with the computer, and bet their points. A bonus that gives four times the points wagered for each round is available if the student answers correctly and wins, while the bet is returned if the bonus is successful and the student loses. Without the bonus option, or if the answer to the bonus option is wrong, the bet is lost if the computer wins, doubled if the student wins. If the students want to succeed in this game, and be rewarded with a place in the high scores list, they must apply the mathematics of counting and probability.

The deck contains at any time of all 52 cards, hence every game is independent of the previously played games. The cards played are visible and must be deducted from the deck as they are played. If, for instance the player has 17 points, the player will exceed 21 by getting 5 or more points on the next card. By looking at the visible cards the cards reminding in the deck are obvious, and the number of cards with the numerical value of 4 or less compared with the number of cards with value 5 or above will tell how risky it would be to draw one more card. If the risk is too big, or bigger than the probability the dealer has to win, then standing with your cards will pay off in the long run.

6.4.4.4 User Interface

The game is fully mouse controlled, but the keyboard may also be used to switch between the buttons. The game is controlled by pressing the buttons at the left side, “Nytt spill”, “Trekk”, and “Stopp” (New game, hit and stand).

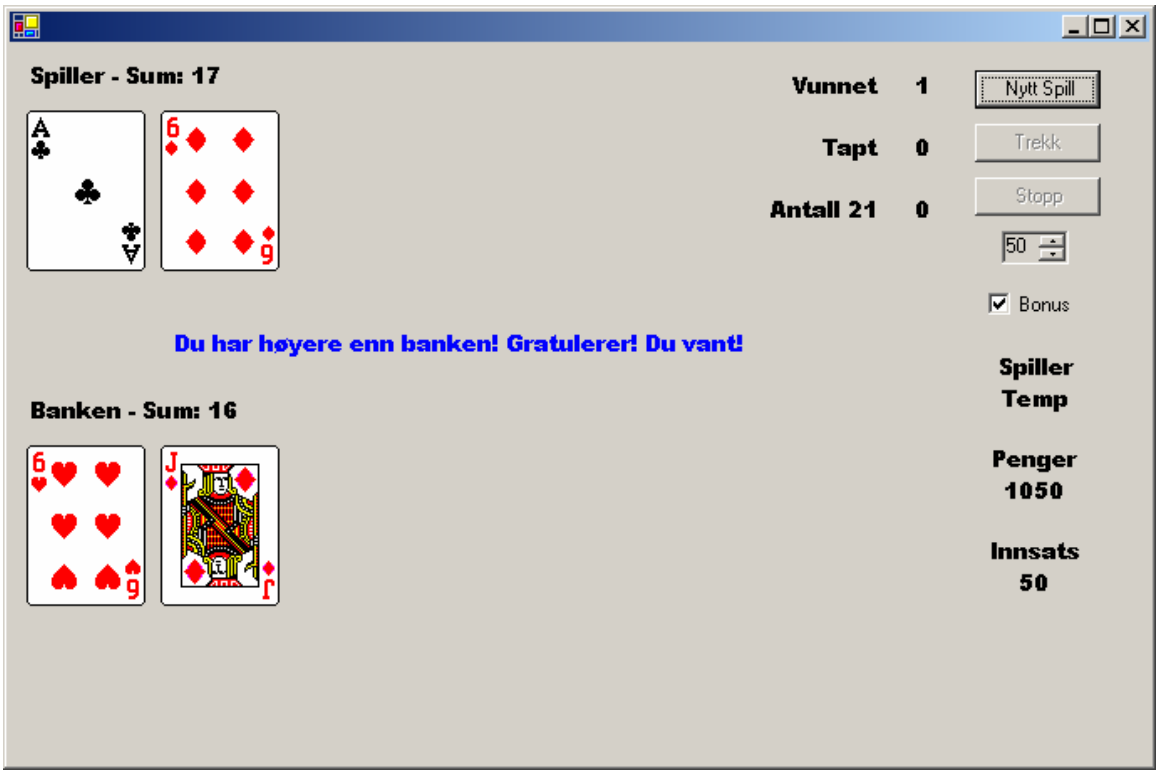


Figure 24: 21 game user interface

By checking the "Bonus" checkbox a probability exercise is available for each round. The student must type in the correct answer to be rewarded with the bonus points.

Figure 25: 21 bonus user interface

7 Conclusion

The literature review shows that there is great potential in using personal computers with active learning. Active learning emphasizes the elaboration of information to create knowledge and understanding and to train the mind for critical thinking. Computers offer to use audio and visual effects combined with interactivity to capture both the students' attention and mind.

The surveys that have been carried out are limited in time and quantity, implicating a weak or inconclusive conclusion. We cannot expect to see distinct differences in the class that has played the game prototype and the class who didn't as the playing time was limited to one hour. Any differences that are detected between the test class and reference class are thus likely to have their source elsewhere. However the results from the surveys give an indication of how this kind of educational methods are received by the target group and to what degree they find these tools helpful in their process of learning.

The goal of educational math games is as we see it is not to replace the current educational system, but to enrich it by taking advantage of the features that personal computers offer. Data collection of the progress and results may provide accurate evaluation reports that may be a great help to the teachers in adapting the local educational environment. The computer based system will also collect information from the students' who do not speak up in class or give feedback by themselves, unveiling the needs of drown voices.

The results from the final survey, performed after the test group had played the game, mainly showed the results as expected. Students who scored high on the math test found the game more satisfactory than those who obtained a low score. As the game is strongly based on solving exercises, we assume that the students proficient in the mathematical methods accelerated at the game and had a stronger feeling of success while those who are not steady in the mathematical methods used may have felt a little lost. Further the games where meant to be played while having the Sinus textbook present, but this was

not always the case for the students who played the game. By integrating the contents of the textbook into the game, with animated examples and solution to problems, the learning experience is likely to be further enhanced.

It is interesting that the survey shows that the gender issue considering who is using computers is vanishing. This is consistent with other surveys performed on the age group 16 to 24 years. Unlike the situation only a few years ago, both females and males use computers on a daily basis. This tendency is important as it shows that the use of computers does not discriminate the genders and that with the correct approach educational computer games will reach out to both girls and boys. [33]

Most of the students agree that new mathematic topics should be presented by the teacher in the traditional way. They see educational computers games as a fun and useful tool to discover practical applications of mathematics and to solve and repeat exercises.

8 References

[1] Utannings- og forskningsdepartementet:
http://odin.dep.no/ufd/norsk/bn.html

[2] Sinus Matematikk 2MX Grunnbok
Tore Oldervoll, Odd Orskaug and Audhild Vaaje

[3] parAbel:
http://www.parabel.no

[4] The Schoolar project:
http://scholar.hw.ac.uk/

[5] The Educational Arcade (MIT):
http://www.educationarcade.org/index.php

[6] The Math Forum:
www.mathforum.org

[7] Behaviorism:
Paper by Susan Darby, 2003

[8] The human brain anatomy:
http://www.vh.org/adult/provider/anatomy/BrainAnatomy/BrainAnatomy.html

[9] The stage theory:
http://www2.gsu.edu/~mstswh/courses/it7000/papers/newpage9.htm

[10] Blooms Taxonomy:
http://chiron.valdosta.edu/whuitt/col/cogsys/bloom.html

[11] Constructivism:
CONSTRUCTIVISM AND EDUCATION: A SHOPPER'S GUIDE, Moses A. Boudourides, 1998
http://www.math.upatras.gr/~mboudour/articles/constr.html

[12] Constructionism:
http://www.papert.org/

[13] Collaborative Learning:
Collaborative Learning Enhances Critical Thinking, Anuradha A. Gokhale, 1995

[14] Cooperative learning:
Tools for Teaching, Barbara Gross Davis, 1993

[15] Spacewar:
http://lcs.www.media.mit.edu/groups/el/projects/spacewar/

[16] MORGP:
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=294828

[17] Educational plan for 2MX:
http://www.ls.no/eway/library/getmessage.asp?objectid=22807&moduleid=125

[18] Constructivism in math education:
http://mathforum.org/mathed/constructivism.html

[19] Teknisk Ukeblad:
http://www.tu.no/nyheter/arbeidsliv/article35397.ece

[20] Information on the status of e-learning:
Bjørn Schinnes, parAbel 2005

[21] Human resources:
http://www.humanresouces.com

[22] Growing up Digital, Don Tapscott 1998:
http://www.growingupdigital.com/

[23] Special Interest Group on Computer-Human Interaction:
http://www.sigchi.org/

[24] The Waterfall development phase model:
Bennet & McRobb, 2002

[25] MSDN: Microsoft C# Overview:
http://msdn.microsoft.com/msdnmag/issues/0900/csharp/default.aspx

[26] MSDN: Microsoft GDI+:
http://msdn.microsoft.com/library/default.asp?url=/library/en-us/gdi/wingdistart_9ezp.asp

[27] MSDN: Microsoft C# documentation:
http://msdn.microsoft.com/msdnmag/issues/02/06/XMLC/default.aspx

[28] nDOC:
http://ndoc.sourceforge.net/

[29] XML:
http://www.w3.org/XML/

[30] Venn Diagram:
http://www.venndiagram.com/intro.html

[31] Evaluering av prosjektet Visuell Matematikk i Agder:
Martin Carlsen, Ingvald Erfjord, Per S. Hundeland, John Madsen og Cornelia Brodal, 2004

[32] History of the card game 21:
http://www.allaboutblackjack.com/history.html

[33] Statistisk sentralbyrå:
http://statbank.ssb.no/statistikkbanken/Default_FR.asp?Maintable=BrukPCWWW&PLanguage=0&nvl=true&PXSid=0&tilside=selectvarval/define.asp&direkte=1

Appendix A
Code documentation

Complete code documentation is available on the CD provided with the report in CHM-format (Compiled HTML help file). This section does not intend to be complete system documentation but will explain the main aspects of the design and the most significant classes that someone interested in expanding the application would depend on.

Design Overview

Namespaces

To avoid conflicts regarding file sharing and other tumbling in each other legs different namespaces and class libraries has been created: Main, Common, ServerCommunication and one for each game module. This is a short briefing of the different namespaces and their domain.

Main

This is the top level namespace. It only contains the main class that initializes a windows frame and the game components. Functionality placed in this layer will have a low level of reusability because of the danger of causing circular references.

Common

A class library that is independent from any game module. The idea is to put classes that have a potential to be reused across the different modules here.

Modules

Each game module has its own library and namespace. This is to ensure that every module is fully independent from each other. However, any module is free to use any components from the .Net-framework and the “Common”-namespace that do not conflict with the rest of the system.

Each module is to inherit the “Module”-class and is to be registered in the “ModuleMap”-instance, initialized through the main class. To avoid complications related to event handling there is only one windows frame that is contained in the main class. The main class forwards all relevant events acquired from the windows frame to the currently running module. The modules in turn are free to use these events directly, or to initialize a modal dialog box. This design enables both the use of .Net components to efficiently make the layout of a game, or to take over the graphics context to give the game a look different from the standard .Net component.

Setup

The class diagram in figure 26 shows the heart of the application. A windows form “Main” initializes a canvas to draw upon and is responsible for receiving system events. The class “ModuleMap” holds a list of game modules. At any time there is one and only one module being player, and the “Main”-class is forwarding all relevant system events to this active module.

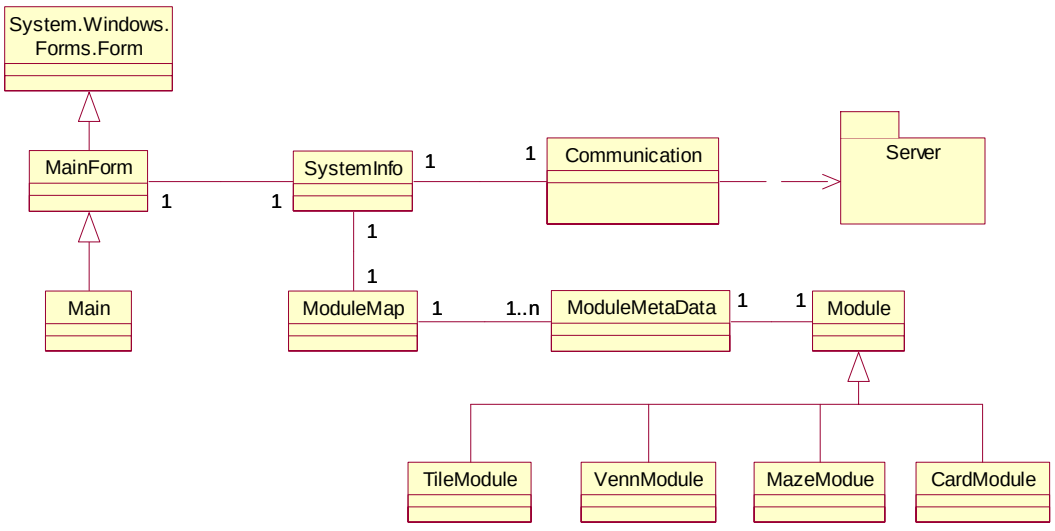


Figure 26: Main setup class diagram

The “ModuleMetaData”-class contains additional information for one module, information that is necessary for the system to know such as when to run the given module. This additional class is necessary to keep the modules separated from the rest of

the system, granting reusability as the module just as well may be run from a completely different setting.

The “Communication” class is responsible for establishing contact and communicating with the game server. Data of progress for each registered user is stored in a database on the server side, serving the purpose of both keeping track of where the users are in the game and providing data to analyze for the teachers.

MainForm

MainForm inherits System.Windows.Forms and is created at the sole purpose of accessing the windows form from other parts of the system. This is typically done to force a refresh of the display.

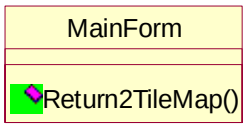


Figure 27: The MainForm class

Return2TileMap

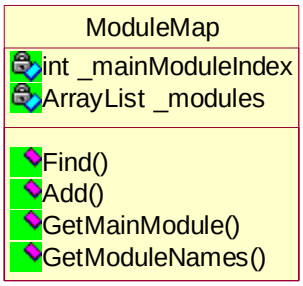
Is to be called when a game module is existing, the main menu module will be started.

ModuleMap

ModuleMap provides a list of all playable modules, with functionally to add and find modules. It also keeps track of which module is the main module, i.e. the main menu module.

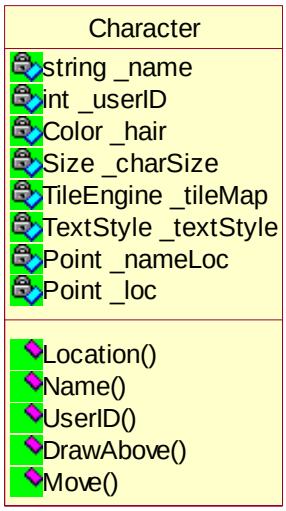
Method	Purpose
Add	Adds a module to the list.
Find	Returns the module object corresponding to the search criteria.
GetMainModule	Returns the main menu module .
GetModuleNames	Returns a list of all module names.

Table 14: ModuleMap methods summary



Character

The Character object represents the logged in player. The class contains information about logon, appearance and location in the game world.

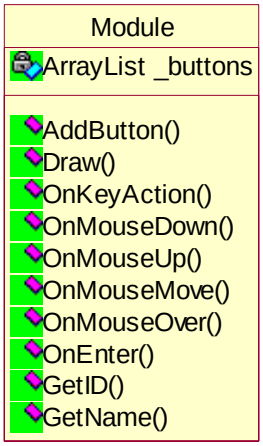


Method	Purpose
Location	Location of the character relative to the game world map represented by the tile engine.
Name	User name (login name) of the player.
UserID	Unique user ID used with server communications.
DrawAbove	Draws the character from above, used to draw the character on top of the world map from an orthographical view.
Move	Moves the character relative to the world map represented by the tile engine. The move is only carried on if it is approved by the tile engine, i.e. if the player attempts to move outside the word or over an obstacle.

Table 15: Character methods summary

Module

The “Module”-class servers as base class for all playable game modules. It provides an interface to forwarding system events that any inheriting class must overload.



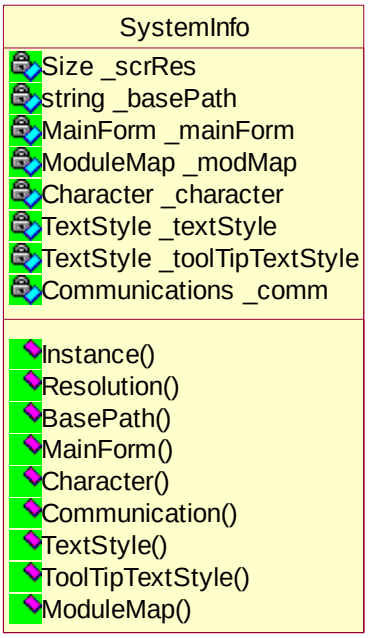
Method	**Purpose**
AddButton	Adds a button to the module and forwards system events to these buttons. This enables custom buttons of any kind to be used in a module.
Draw	Call Draw when display is refreshed.
OnKeyAction	Call OnKeyAction to notify when a keyboard button has been pressed.
OnMouseDown	Call OnMouseDown to notify when a mouse button has been pressed.
OnMouseUp	Call OnMouseUp to notify when a mouse button has been released
OnMouseMove	Call OnMouseMove to notify when the mouse has been moved.
OnMouseOver	Call OnMouseOver to notify when the mouse has been hovering about a point for a given delay.

OnEnter	Call OnEnter to notify that the module is being run.
GetID	Returns module ID, as used with server communication.
GetName	Returns a textual name or description of the module.

Table 16: Module methods summary

SystemInfo

SystemInfo is a singleton class that grants easy access to vital system information. Singleton is a pattern that ensures that at most one instance of the class may exist at the same time. The Instance() method returns this only instance and it is static to provide a global point of access to it.



Method	**Purpose**
Instance	Grants a global point of access to all other members.

Resolution	Returns the system's screen resolution.
BasePath	Returns the path of the executable file. Additional files, such as images and xml-files are stored relatively to this file path.
MainForm	Returns the MainForm instance. Typically used to force a display update or similar.
Character	Returns the character object for server access or similar.
TextStyle	Returns default system text style.
ToolTipTextStyle	Returns textstyle to be used with tooltips.
ModuleMap	Returns the ModuleMap that grants access to the different modules.

Table 17: SystemInfo methods summary

World module Design

"TileModule" inherits from "Module". Events that occur are forwarded to the character and TileEngine as required.

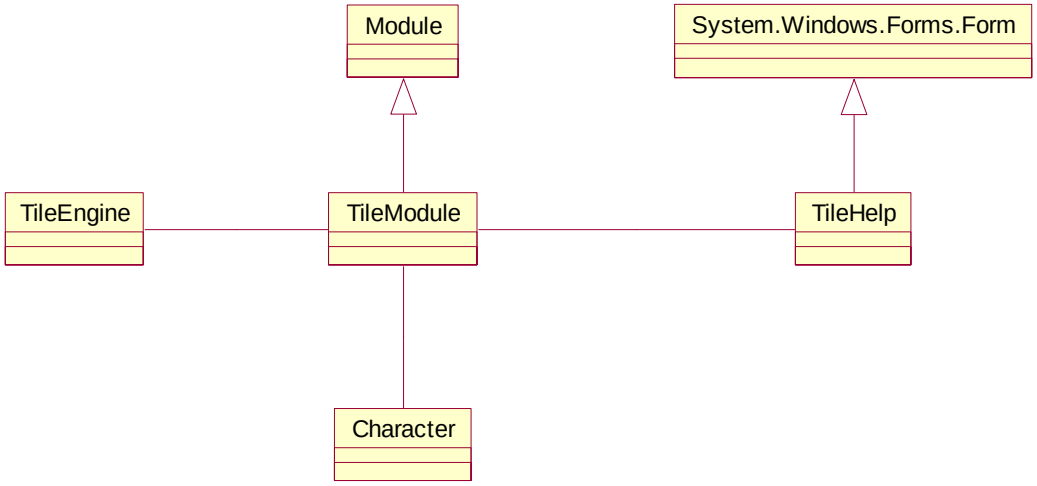


Figure 28: The TileModule design

Venn diagram game module design

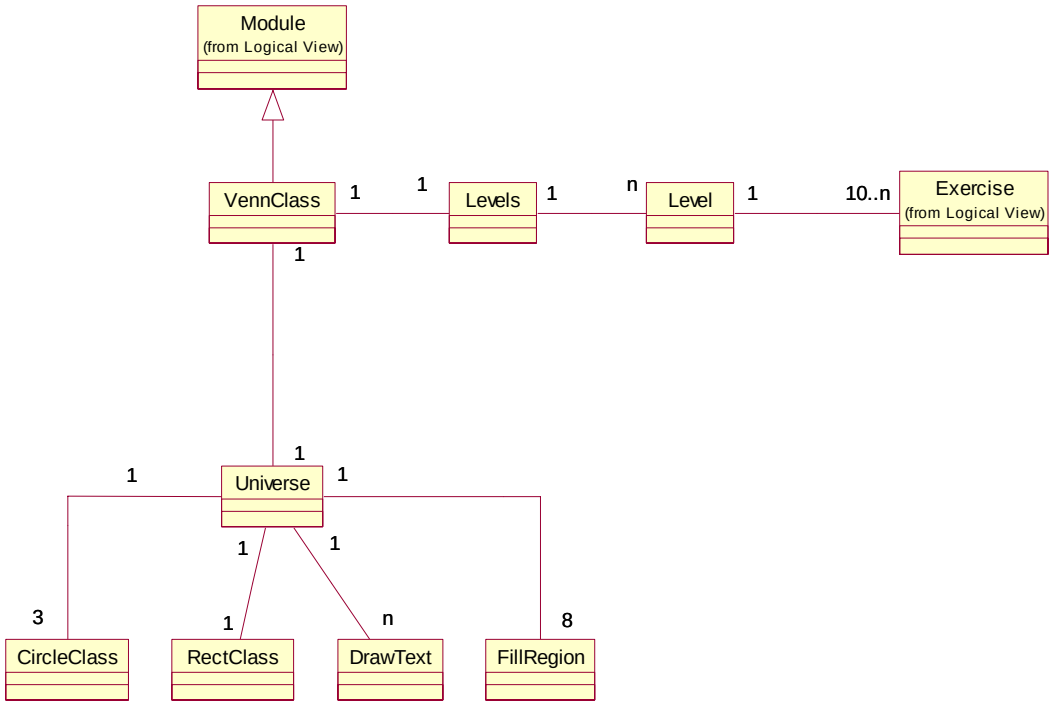


Figure 29: Venn class diagram

VennClass

Inherits from Common.Module and handles all system events. VennClass contains a list of levels that is responsible for providing suitable exercises, and an Universe-object that is responsible for drawing graphics.

Contains a list of levels and functionality to access these.

Provides functionality to parse exercise from XML files of the given format:

```
- <exercise id="1001" level="1">
    <Question>Hvor passer en TIGER inn?</Question>
    <CircleText>Kattedyr</CircleText>
    <CircleText>Planteeter</CircleText>
    <CircleText>Firbeint</CircleText>
    <CorrectSelection>00000100</CorrectSelection>
  </exercise>
```

Tag	Function
ID	Unique exercise ID
Level	Idicates what level this exercise belongs to.
Question	Question text.
CircleText	Text belonging to one of the circles or sets. This tag may appear up to three times in order A,B and C.
CorrectSelection	The Venn diagram containing three sets has 8 subsets, with the universe included. The 1's indicate what subsets are to be selected for the answer to be approved. The figure below shows what subset correcspond to each position in this 8 bit string.

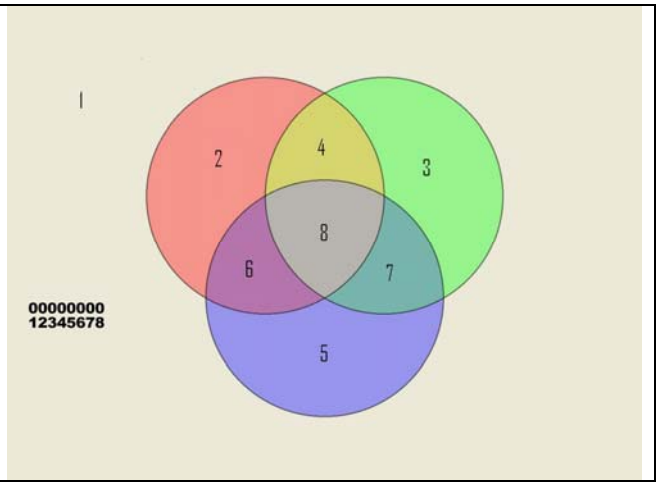
	

Table 18: Venn game XML format

Level

Contains two lists of exercises. The first list is the original list that at any time contains all the exercises for the given level. The other list contains the exercises that are yet to be played in this level. When the level is restarted the original list is copied into the contemporary list.

A level must contain at least 10 exercises.

Exercise

Contains one exercise with exercise text, set labels and the correct answer.

Universe

The Universe object is responsible for the graphical representation of the game. It contains

CircleClass

Contains functionality to calculate the size and position of the sets represented as circles, and to draw the circle outlines.

RectClass

Draws the universe, that is all the elements that are not in set A,B or C.

DrawText

FillRegion

The FillRegion object represents one subset. It contains functionality to draw the subsets, both as regular and selected, and the functionality to determine whether a point, i.e. the mouse pointer, is inside the subset or not.

Maze game module design

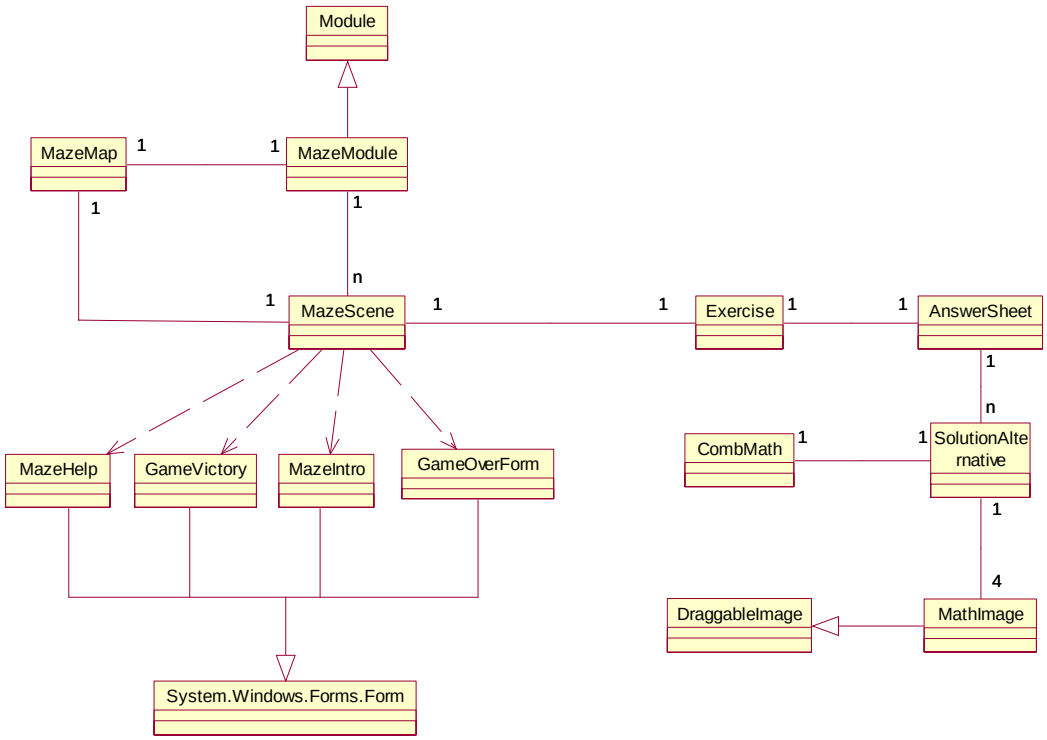


Figure 30: Maze game class diagram

MazeHelp, GameVictory, MazeIntro, GameOverForm

These are all dialog boxes that provide information to the player.

MazeModule

The maze module inherits the Module-class and receives all relevant events from the windows frame. It contains a scene graph or a list of MazeScenes and keeps track of

which level is currently being played. It also contains information that is common for the entire maze game, such as the clock, buttons and whether “helpmode” is enabled.

MazeScene

The “mazeScene”-class represents one level or location of the game. The class contains the background and foreground images for the level and an exercise object, which in turn represents the exercise to be solved.

Each MazeScene is automatically navigable to its adjacent MazeScenes, hence all the scenes must form some sort of structure. The highest level scene will always function as the final scene.

The entire maze scene graph may be loaded from and XML file.

```
- <MazeScene>
    <Name>MS1</Name>
    <Location>1,0</Location>
    <Paths>MS2</Paths>
    <Buttons>ButtonHelp,ButtonCheckAnswer,ButtonNorth,ButtonSouth,ButtonEast,ButtonWest</Buttons>
    <Exercise>Exer1</Exercise>
    <AnswerArea>0,500;1024,768</AnswerArea>
    <BackgroundImage>Images\backgrnd1.jpg</BackgroundImage>
  - <ImageObject>
      <FileName>Images\lessondw5.jpg</FileName>
      <Position>100,100</Position>
    </ImageObject>
  </MazeScene>
```

Figure 31: Scene XML declaration

Tag	Function
Name	Name of the scene. Must be unique for system.
Location	Location of the scene. Must be unique for the system
Paths	Connects neighbor scene(s) to this scene by scene name(s). The player can only move from this scene to the scene(s) listed here, even if they have adjacent locations
Exercise	Name reference to belonging exercise
BackGroundImage	File reference to background image. Note that the path is relative to

	the default path of the game
ImageObject	Overlay image. Is drawn on top of the background image. **Tag** — **Function** FileName — File reference. Relative to default game file path. Position — Position in pixels relative to the upper left corner and the size of the background image.

Table 19: Scene XML tags

MazeMap

This object builds a generic overview map of the scene graph. Each level is graphically represented by a square where the colors yellow, green and blue represents if the level is unexplored, completed or if it is currently being played.

Exercise

The exercise object represents an exercise to be solved by the player. An exercise is built up of an exercise text property; a property that denotes what answers must be delivered for the exercise to be completed.

An exercise dictionary or collection of exercises may be built from an XML file of the following format.

```
- <Exercise>
    <Deliverables>Answer,Formula,Calculations</Deliverables>
    <Text>Regn ut 5!</Text>
    <Name>Exer1</Name>
    <Position>150,50</Position>
  - <Factorial>
      <Correct>true</Correct>
      <Visible>Answer,Calculations,Formula</Visible>
      <Position>0,0;800,280;815,330;745,400</Position>
      <Data>5</Data>
    </Factorial>
  - <Factorial>
      <Correct>false</Correct>
      <Visible>Answer,Calculations</Visible>
      <Position>0,0;0,0;820,466;900,730</Position>
      <Data>6</Data>
    </Factorial>
  - <Factorial>
      <Correct>false</Correct>
      <Visible>Answer,Calculations</Visible>
      <Position>0,0;0,0;790,380;930,300</Position>
      <Data>4</Data>
    </Factorial>
  - <Factorial>
      <Correct>false</Correct>
      <Visible>Answer,Calculations</Visible>
      <Position>0,0;0,0;900,425;785,435</Position>
      <Data>3</Data>
    </Factorial>
  </Exercise>
```

Figure 32: Exercise XML format

Tag	Function
Name	Unique identifier for exercise object.
Deliverables	Appropriate values: “Method”, “Formula”, “Calculations” and “Answer”. For every deliverable listed here a corresponding answer box is displayed. All of these boxes must contain the correct answer for the exercise to be approved.
Text	Textual exercise.
Position	Location in pixels relative to upper left corner of windows frame of where the exercise text box is displayed.

Table 20: Exercise XML tags

As the multiple choice delivery strategy is used, several answer alternatives are provided with the exercise definition.

Tag	Function
Factorial, Arrangement, Binominal, Permutation	Type of combinatorial math object.
Positions	The location attributes are assigned in the following order: Method, Formula, Calculations, Answer. The x and y-values are separated by a ‘,’, and each location is separated by a ‘;”.
Visible	Appropriate values: Method, Formula, Calculations, Answer. May contain from one to all four of them. The listed items will be displayed in the pool of solution alternatives and are available to the player.
Data	Number. For example for a Factorial object, the number 3 denotes 3! = 6.

Table 21:Combinatorial math element XML tags

AnswerSheet

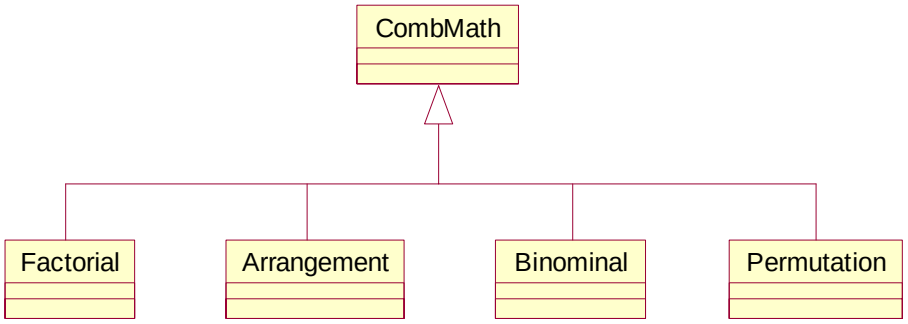
A collection of “SolutionAlternatives”. One of the “SolutionAlternatives” is correct, while the remaining alternatives are incorrect.

SolutionAlternative

A “SolutionAlternative” represents one alternative to the solution. A Boolean value indicates if this is the correct answer or not.

CombMath

“CombMath” is the base class for all combinatorial math objects. The available types are factorial, arrangement, binominal and permutations.



MathImage

Inherits from “DraggableImage”. The available items from the “CombMath”-object is drawn onto “MathImages” to optimize refresh rates.

Casino game module design

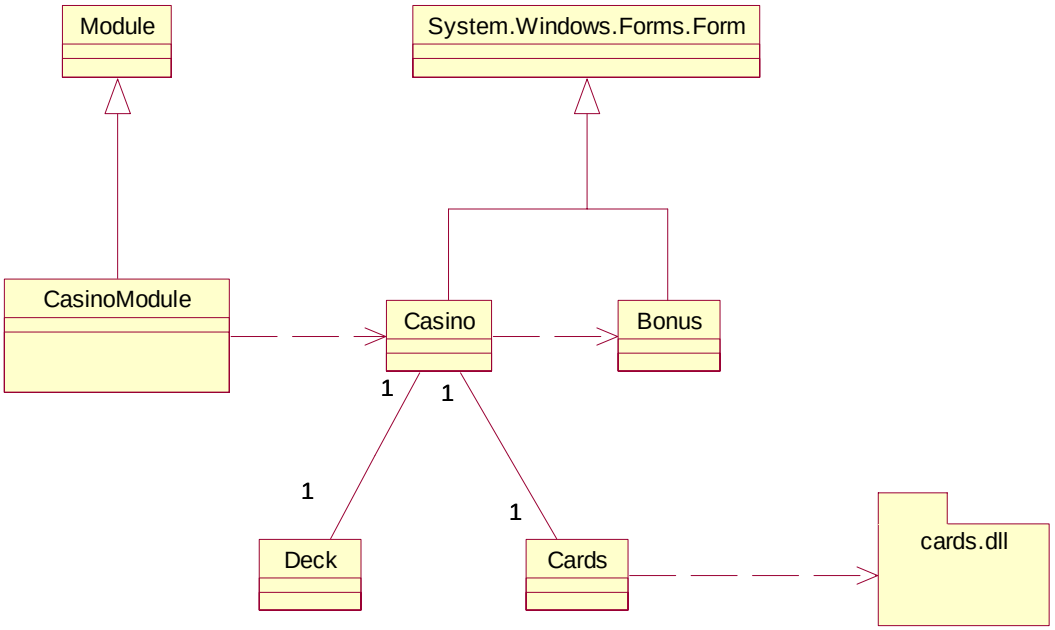


Figure 33: Casino class diagram

The Casino module is based on a dialog box. This dialog box is initiated and run from the CasinoModule object. “Cards.dll” is a library that comes with Microsoft Windows.

Appendix B

Questionnaire Results

		Kjønn?	Hvor mye tid bruker du ukentlig på matte?	Hvor flink er du i matte?	Liker du matematikk?	Ditt brukernavn(det du registrerte i spillet):	Lærte du noe, eller fikk bedre forståelse for noe ved å spille?	Hva var bra med spillet?	Hva var ikke bra med spillet?	Hva bør være med i slike spill?	Kjønn	Hvor mange timer bruker du på matematikklekser ukentlig?	Hvor flink er du i matte?	Hvor godt liker du matematikk?	Hvor mye nytte tror du at du kunne ha av spill som læremiddel?	Hva er ditt nivå når det gjelder sannsynlighetsregning og kombinatorikk?	Hva mener du kan spillbasert læring kan/ikke kan brukes til?	Correct	%Correct
		Q1	Q2	Q3	Q4	1,1	1,2	1,3	1,4	1,5	2,1	2,2	2,3	2,4	3,1	3,2	3,3		
Class 1	Have played the game	0	0	3	4										3	3		4	40,0 %
		1	0	2	2										x	x		3	30,0 %
		1	4	1	1										3	2		4	40,0 %
		1	0	3	4														0,0 %
		0	1	2	2														0,0 %
		1	0	3	3														0,0 %
		1	0	1	1										x	x		3	30,0 %
		1	0	2	2										2	3		2	20,0 %
		1	0	3	3										3	2		2	20,0 %
		1	2	2	4										3	3		4	40,0 %
		0	1	2	3										3	3		0	0,0 %
		1	0	2	2										3	3		5	50,0 %
		1	1	2	4										3	2		3	30,0 %
		0	2	2	4										4	3		7	70,0 %
		1	0	2	3										3	2		3	30,0 %
		1	0	2	2										3	2		4	40,0 %
		1	0	3	3										2	3		2	20,0 %
		1	0	2	2										3	3		8	80,0 %
		1	0	4	4														0,0 %
		1	0	4	2														0,0 %
		1	0	0	0														0,0 %
		0	0	3	3														0,0 %
		1	4	4	3														0,0 %
	Haven't played the game										2	1	4	3	3	2		1	10,0 %
											1	2	5	5	4	2		4	40,0 %
											1	3	4	5	3	3		1	10,0 %
Class 2											1	1	4	4	4	3		2	20,0 %
											1	1	4	3	3	4		5	50,0 %
											1	3	4	3	3	3		7	70,0 %
											1	2	3	4	4	2		5	50,0 %
											2	1	2	2	3	2		3	30,0 %
											2	2	5	5	5	4		4	40,0 %
											1	2	5	5	3	3		7	70,0 %
											1	2	5	4	4	4		7	70,0 %

Appendix C

Game Results

ResID	UserID	Level	Score	hits	tries	date	time	minutes between results	increase in score
208	39	1	0	4	0	04.05.2005	12:49:56		
211	39	1	0	8	0	04.05.2005	12:50:45	0,8	0
230	39	1	4550	5	5	04.05.2005	12:55:11	4,4	4550
233	39	2	16150	7	6	04.05.2005	12:56:01	0,8	11600
268	39	3	34900	7	7	04.05.2005	13:06:41	10,7	18750
278	39	4	34900	29	2	04.05.2005	13:09:26	2,7	0
293	39	2	31550	8	8	04.05.2005	13:15:48	6,4	-3350
308	39	3	57650	9	9	04.05.2005	13:19:37	3,8	26100
320	39	4	57650	8	6	04.05.2005	13:23:04	3,4	0
184	40	1	0	14	3	04.05.2005	12:42:00		-57650
221	40	1	0	14	3	04.05.2005	12:53:19	11,3	0
234	40	1	0	15	3	04.05.2005	12:56:09	2,8	0
238	40	1	4700	5	5	04.05.2005	12:57:20	1,2	4700
245	40	2	16300	7	6	04.05.2005	12:58:08	0,8	11600
253	40	3	16300	0	0	04.05.2005	13:00:22	2,2	0
264	40	2	29600	8	7	04.05.2005	13:04:41	4,3	13300
281	40	3	52700	8	8	04.05.2005	13:11:58	7,3	23100
300	40	4	52700	57	7	04.05.2005	13:17:16	5,3	0
166	41	1	0	0	0	04.05.2005	12:24:03		-52700
225	41	1	0	2	0	04.05.2005	12:54:32	30,5	0
231	41	1	0	6	1	04.05.2005	12:55:19	0,8	0
235	41	1	0	1	0	04.05.2005	12:56:25	1,1	0
247	41	1	0	8	1	04.05.2005	12:58:36	2,2	0
267	41	1	3750	6	5	04.05.2005	13:06:30	7,9	3750
277	41	2	15450	6	6	04.05.2005	13:08:49	2,3	11700
283	41	3	15450	15	5	04.05.2005	13:13:03	4,2	0
291	41	1	6400	7	7	04.05.2005	13:15:24	2,4	-9050
294	41	2	22000	9	8	04.05.2005	13:15:59	0,6	15600
296	41	3	22000	5	1	04.05.2005	13:16:24	0,4	0
168	42	1	0	6	2	04.05.2005	12:26:33		-22000
195	42	1	0	19	4	04.05.2005	12:44:57	18,4	0
196	42	1	4700	5	5	04.05.2005	12:45:22	0,4	4700
209	42	2	4700	5	1	04.05.2005	12:49:58	4,6	0
210	42	2	15500	6	6	04.05.2005	12:50:41	0,7	10800
251	42	3	35450	8	7	04.05.2005	12:59:55	9,2	19950
304	42	4	66250	8	8	04.05.2005	13:18:44	18,8	30800
319	42	5	66250	12	0	04.05.2005	13:23:03	4,3	0
213	43	1	4500	6	5	04.05.2005	12:51:35		-61750
236	43	2	15500	7	6	04.05.2005	12:56:35	5,0	11000
262	43	3	34550	8	7	04.05.2005	13:03:49	7,2	19050

299	43	4	64550	9	8	04.05.2005	13:17:14	13,4	30000
312	43	5	64550	7	1	04.05.2005	13:22:20	5,1	0
198	44	1	0	0	0	04.05.2005	12:46:48		-64550
199	44	1	0	1	0	04.05.2005	12:47:00	0,2	0
202	44	1	0	5	2	04.05.2005	12:48:01	1,0	0
214	44	1	4500	6	5	04.05.2005	12:51:44	3,7	4500
243	44	2	15900	6	6	04.05.2005	12:57:58	6,2	11400
258	44	3	35850	8	7	04.05.2005	13:02:24	4,4	19950
259	44	4	35850	0	0	04.05.2005	13:03:21	0,9	0
286	44	2	31500	9	8	04.05.2005	13:13:49	10,5	-4350
307	44	3	57600	9	9	04.05.2005	13:19:33	5,7	26100
317	44	4	57600	12	4	04.05.2005	13:22:29	2,9	0
170	45	1	0	8	4	04.05.2005	12:26:57		-57600
189	45	1	0	0	0	04.05.2005	12:43:16	16,3	0
204	45	1	4700	5	5	04.05.2005	12:48:24	5,1	4700
222	45	2	15200	6	6	04.05.2005	12:53:43	5,3	10500
311	45	3	30200	8	7	04.05.2005	13:21:48	28,1	15000
315	45	4	30200	1	1	04.05.2005	13:22:28	0,7	0
205	46	1	0	1	0	04.05.2005	12:48:56		-30200
223	46	1	0	6	3	04.05.2005	12:54:02	5,1	0
229	46	1	4650	6	5	04.05.2005	12:55:07	1,1	4650
241	46	2	16350	6	6	04.05.2005	12:57:54	2,8	11700
248	46	3	16350	64	3	04.05.2005	12:59:08	1,2	0
266	46	3	16350	3	1	04.05.2005	13:06:13	7,1	0
200	47	1	4650	6	5	04.05.2005	12:47:25		-11700
207	47	2	16350	6	6	04.05.2005	12:49:47	2,4	11700
218	47	3	16350	9	3	04.05.2005	12:53:04	3,3	0
169	48	1	4850	5	5	04.05.2005	12:26:50		-11500
172	48	2	4850	1	1	04.05.2005	12:28:47	1,9	0
212	48	2	15950	6	6	04.05.2005	12:50:56	22,2	11100
265	48	3	15950	1	0	04.05.2005	13:05:13	14,3	0
270	48	2	27750	8	7	04.05.2005	13:06:52	1,6	11800
288	48	3	50250	9	8	04.05.2005	13:14:10	7,3	22500
316	48	4	50250	15	2	04.05.2005	13:22:28	8,3	0
220	49	1	0	1	0	04.05.2005	12:53:17		-50250
252	49	1	4700	5	5	04.05.2005	12:59:59	6,7	4700
260	49	2	16000	7	6	04.05.2005	13:03:28	3,5	11300
285	49	3	16000	7	3	04.05.2005	13:13:23	9,9	0
287	49	1	4700	7	3	04.05.2005	13:13:59	0,6	-11300
314	49	1	4700	5	5	04.05.2005	13:22:27	8,5	0
217	50	1	0	0	0	04.05.2005	12:52:29		-4700
228	50	1	0	8	2	04.05.2005	12:55:00	2,5	0
232	50	1	0	0	0	04.05.2005	12:55:45	0,8	0
237	50	1	0	18	2	04.05.2005	12:56:40	0,9	0
239	50	1	0	0	0	04.05.2005	12:57:29	0,8	0
244	50	1	4500	6	5	04.05.2005	12:58:02	0,6	4500
263	50	2	15900	6	6	04.05.2005	13:03:55	5,9	11400
282	50	3	15900	29	5	04.05.2005	13:12:01	8,1	0
290	50	1	10750	7	7	04.05.2005	13:15:05	3,1	-5150

292	50	2	26350	9	8	04.05.2005	13:15:34	0,5	15600
297	50	3	26350	23	7	04.05.2005	13:17:06	1,5	0
301	50	1	4500	23	7	04.05.2005	13:18:12	1,1	-21850
305	50	1	13350	9	9	04.05.2005	13:18:44	0,5	8850
306	50	2	32950	11	10	04.05.2005	13:19:25	0,7	19600
313	50	3	32950	11	4	04.05.2005	13:22:22	2,9	0
190	51	1	0	5	3	04.05.2005	12:43:56		-32950
226	51	1	4550	5	5	04.05.2005	12:54:38	10,7	4550
242	51	2	15650	6	6	04.05.2005	12:57:56	3,3	11100
269	51	3	15650	5	2	04.05.2005	13:06:47	8,9	0
275	51	2	27550	7	7	04.05.2005	13:08:13	1,4	11900
318	51	3	27550	4	3	04.05.2005	13:23:03	14,8	0
256	52	1	0	20	4	04.05.2005	13:01:21		-27550
257	52	1	0	20	4	04.05.2005	13:01:37	0,3	0
272	52	1	0	17	3	04.05.2005	13:07:15	5,6	0
276	52	1	4350	6	5	04.05.2005	13:08:46	1,5	4350
295	52	2	4350	8	5	04.05.2005	13:16:11	7,4	0
167	53	1	0	1	0	04.05.2005	12:25:20		-4350
227	53	1	0	1	1	04.05.2005	12:54:58	29,6	0
240	53	1	5000	5	5	04.05.2005	12:57:52	2,9	5000
254	53	2	16000	7	6	04.05.2005	13:01:17	3,4	11000
280	53	3	16000	16	3	04.05.2005	13:09:50	8,6	0
246	54	1	0	3	1	04.05.2005	12:58:21		-16000
250	54	1	0	2	0	04.05.2005	12:59:54	1,5	0
255	54	1	4500	6	5	04.05.2005	13:01:18	1,4	4500
261	54	2	16100	7	6	04.05.2005	13:03:39	2,4	11600
273	54	3	16100	14	4	04.05.2005	13:07:57	4,3	0
289	54	1	0	14	4	04.05.2005	13:14:54	6,9	-16100
171	55	1	4800	6	5	04.05.2005	12:28:07		4800
179	55	2	15900	6	6	04.05.2005	12:38:05	10,0	11100
187	55	3	15900	4	3	04.05.2005	12:42:43	4,6	0
274	56	1	5000	5	5	04.05.2005	13:08:05		-10900
279	56	2	17000	6	6	04.05.2005	13:09:45	1,7	12000
298	56	3	36950	8	7	04.05.2005	13:17:09	7,4	19950
303	56	4	36950	32	1	04.05.2005	13:18:42	1,6	0
321	58	1	5000	5	5	04.05.2005	06:26:25		-31950
322	58	2	17000	6	6	04.05.2005	06:26:44	0,3	12000
323	58	3	36650	7	7	04.05.2005	06:32:49	6,1	19650
324	58	4	67450	8	8	04.05.2005	06:37:43	4,9	30800
326	58	4	86650	6	5	05.05.2005	13:07:01	389,3	19200
327	58	5	86650	2	1	05.05.2005	13:07:55	0,9	0
329	59	1	5000	5	5	05.05.2005	06:21:33		-81650
330	59	2	17000	6	6	05.05.2005	06:21:49	0,3	12000
331	59	3	38000	7	7	05.05.2005	06:28:13	6,4	21000
332	59	4	38000	1	1	05.05.2005	06:48:40	20,5	0
333	60	1	4700	5	5	05.05.2005	07:16:57		-33300
334	60	2	4700	8	5	05.05.2005	07:18:48	1,8	0
335	60	2	16400	6	6	05.05.2005	07:20:22	1,6	11700
336	60	3	16400	3	3	05.05.2005	07:23:12	2,8	0

Appendix D
Bundled CD

The bundled CD contains this report, the source code project and complete code documentation in “Compiled HTML help file”-format.