

Multi Media eLearning Software TRIANGLE Case-Study: Experimental Results and Lessons Learned

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Abstract: This paper reports on results of experiments carried out with TRIANGLE. The software has been designed and developed since 2001 in several modifications as an experimental prototype for an interactive multimedia learning object. During the design, it was essential to provide a user interface with good usability in order to support the teachers with only a minimum knowledge of computers. It was also necessary to provide a simple data structure and open architecture including runtime evaluation. The basic idea was to provide a quiz show game in order to uphold as strong a level of motivation as possible. The purpose of this prototype was to test the efficiency of three main psychological concepts in terms of learning: motivation, incidental learning, and something we call the *Tamagotchi effect*, which refers to the concept of personal responsibility. A pre-test/post-test control group design was chosen. The experiments were carried out in real-life classroom settings including N=44 K8 students. Mathematics was chosen as the subject. Three hypotheses were tested: 1) This game based learning software provides a level of motivation high enough to make learning fun, even with less popular subjects; 2) *Chunks of knowledge* mixed into informational text, within a hypertext structure, are efficient enough to facilitate student learning; 3) An additional virtual partner (avatar), to which a student feels personal responsibility, further increases motivation. Based on the results of our studies, hypotheses 1 and 2 could be proven, however, *not* hypothesis 3. Consequently, TRIANGLE can stimulate learning by making unpopular subjects fun; incidental learning can increase the process of integrating new knowledge; however, no positive effect could be measured of the personal responsibility for the avatar, possibly due to the low occurrence of personalization within the experimental settings.

Keywords: Educational multimedia software, motivation, incidental learning, Tamagotchi-Effect

Categories: TH.AP, TO.6, TO.7, TO.27

"A reward a day makes work out of play [Zimbardo, '99]"

1 Introduction

1.1 From Behavioristic to Constructivistic Learning

Both educational software and classroom teaching are undergoing a continual change of paradigms. Whilst intentional learning is commonly connected with Behaviorism [Skinner, '53], [Skinner, '58], not all kinds of learning can be explained this way. Constructivists explain the world as a “web of facts”: gaining knowledge involves not only learning these facts but finding connections between already known and new chunks of information [Papert, '91], [Norman, '96], [Motschnig-Pitrik, '02], [Holzinger, '05]. This brings a type of learning into the foreground, which is often ignored – incidental learning (refer to section 3.3 for details).

With TRIANGLE we developed modular learning software, implementing some ideas and motivational techniques of the state of the art multimedia development and tested the prototype with end-users in a real-life setting, following a wide spectrum of usability engineering methods [Holzinger, '05].

While appearing to be just another piece of educational software, the purpose of TRIANGLE was primarily to provide a test-bed for examining some new principles and ideas [Holzinger, et al., '01]. Some of the ideas were originally based on a Web based training environment called VR-Friends [Holzinger, '99].

1.2 Motivation for our Research

We have been stimulated by the facts that game shows and trivia quiz shows have been popular ever since television became broadly available [Wexler, '94]. The enormous success of games including Trivial Pursuit led to Jeopardy; however, one of the most popular examples is “Who Wants to be a Millionaire”, with similar shows in almost every country worldwide. Not only on television, also trivia quiz terminals in pubs or other public places are popular and of course internet-based game shows increasingly court the surfer’s favor.

We observed people participating in this shows and noticed that a considerable amount of knowledge is accumulated, although these people surely not intended to “learn” [Holzinger, '99]. The ideas behind game shows are simple yet powerful (see next chapters).

While other kind of games are based on a single talent or at least some kind of special capability (fast reactions, strength, etc.), everybody has collected knowledge of every kind during their lifetime and will be able at least to answer some of the questions. In order to satisfy the target audience, there are two strategies: the questions refer only to a very special field of interest (e.g. football, pop music, automobiles, etc.) or to a huge variety of interests. In the second case the questions are usually kept simple, consequently everybody will be able to answer some of them. It is important that moments of success occur from time to time (a question is answered correctly). Even more important however, is the fact that the candidate is learning while playing, because they are forced to answer a question in a very prominent position or under

pressure (e.g. running clock). In any case there is a high probability that they will memorize the correct answer (independent of their own answer!) compared to a standard learning situation (e.g. reading a fact in a book).

2 What is TRIANGLE?

The final test bed used in our case study was called TRIANGLE due to the fact that mathematics was chosen as the subject for our experiments and we concentrated on the topic of trigonometry. The application is similar to an "educational media player", subsequently our software can of course be used with any other subject of interest.

The implemented Lesson can best be described as "everything to do with the right angled TRIANGLE". However, the creation of just another piece of software for learning purposes was not our intention during the design of TRIANGLE; our primary aim was to integrate, test and experiment with new psychological and educational concepts in real-life scenarios.



Figure 1: "TRIANGLE – the geometrical game show"

Consequently, TRIANGLE is designed as a computer game, with the aim of providing a high level of motivation and fun. Normally children (and of course some adults) love playing more than learning [Wood, '98] and this special learning software allows them to play a quiz show game – learning is just a means to an end. Important issues of TRIANGLE include graphic design, sound ambience and game play, which have a much different appearance than other common learning software.

Briefly, the player's task in TRIANGLE is to achieve as high a score as possible by answering ten questions. The player is represented by a virtual partner and competes against two opponents. As preparation and in order to get accustomed to the game show the player can learn in a special training center, where his virtual counterpart joins him and is also able to learn. In the game show the virtual partner can answer questions instead of the player, the more intense the training phase is, the higher the probability of a correct answer of the partner. Every question is worth a certain amount of points (score).

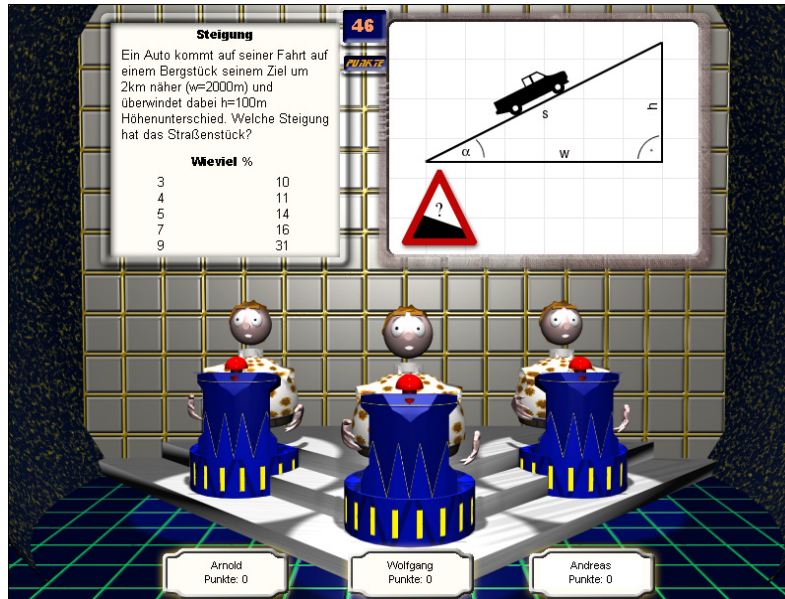


Figure 2: Screen shot of the game show

A counter shows the possible points; after a short period during which the player can read the question, this counter decreases every second. Now, the (virtual) opponents also try to answer. Correct answers are rewarded with the remaining points; however, wrong answers are punished by deducting 20 points from the player's current score.

TRIANGLE can be best described as a prototype of an open educational software system. It was important that any teacher, even with low computer literacy, can change or add content and build a version to match his or her specific needs. This is achieved by using a very simple plain text hypertext format in combination with strict digital image and video specifications.

In every day use, teachers could create their own textual content (and share it with other teachers) while multimedia elements that are not as easy to produce could be downloaded from a central education server.

TRIANGLE was used in our case study to prove or disprove three hypotheses:

- This game like learning software provides a level of motivation high enough to make it fun learning even unpopular subjects;
- Chunks of knowledge" mixed into informational text in a hypertext structure can be used to teach students;
- An additional virtual partner (avatar), to which the student feels personal responsibility, causes an increase in motivation.

3 Theoretical Background

A big problem in every successful learning session is maintaining the motivation for continued learning. This problem is most crucial if the material is difficult to understand and/or the learners do not have much personal interest in the material, which unfortunately is often happens in mathematics [Holzinger, '97]. In learning as such, we have on the one hand intentional learning – used in traditional computer assisted learning systems – and on the other we have incidental learning [Holzinger and Maurer, '99].

3.1 Play as Stimulus to Learning

Children learn, interact with others, and nurture their creativity through play. It is common that especially small children do not make a distinction between play and learning, play and work, and fantasy and reality. However, child's play is metaphorically work. Subsequently, the concept of play can enhance our comprehension and inspire the creation of stimulating environments for children and – not exclusively for them. Consequently, the notion of play has intrigued educators for a long time [Dewey, '16], [Piaget, '51], [Rubin, '82].

However, no simple definition exists. Play is a complex but still poorly understood phenomenon that is generally misconceived as frivolous. Yet, our knowledge of cultural evolution indicates that play is to be taken seriously. Play can be considered as a critical aspect of children's lives that is essential to their intellectual, cognitive, spiritual, spatial and emotional development. Considering the notion of play and its implications to learning as important and if we accept that the notion of play can be useful, then a natural extension of this is to look at environments where play can be used successfully [Reiber, '96].

Piaget (1962) [Piaget, '62] argued that play is the vehicle through which children interact with their environment and construct their knowledge. We can subsume that Piaget's ideas about play have been the most influential of the last century.

His premise is that children are constantly constructing their knowledge of the environment as they interact with objects and people. Piaget uses elegant concepts including assimilation and accommodation to develop a seamless relationship between play and learning; he argues that they have a symbiotic relationship. Assimilation refers to a child's ability to take material from an environment and incorporate it into his or her way of thinking about the world, whilst accommodation pertains to how a child's perception is transformed by stimuli from this environment. The primacy of assimilation over accommodation is play, whereas the primacy of accommodation over assimilation is learning. In this sense, Piaget's ideas have much in common with the constructivist perspective of learning (cf. with [Rubin and Pepler, '82]).

Seymour Papert was a colleague of Piaget in the early 1960s. He was convinced of Piaget's theory of constructivism but wanted to extend Piaget's theory of knowledge to

the fields of learning theory and education. He wanted to create a learning environment that was more beneficial to Piaget's theories.

It is also interesting that he saw conventional school environments as too “sterile, too passive, too dominated by instruction”. Such environments did not allow children to be the active builders that he were convinced they were. It seems also amusing that being a mathematician by training, Papert could not help wondering why most mathematics classes were so unlike as other classes. Consequently, Papert observed that math classes – by comparison – were mostly dull, boring, unengaging, passive, dominated by instruction and anything else but fun. On the other hand, however, he knew from his own experience that the subject of mathematics itself is exciting, beautiful, challenging, engaging and very creative. He asked, why was it being ruined for so many children? [Papert, '85].

However, the development of such software is challenging, especially the user interface, since children are an extremely inhomogeneous user group [Markopoulos, '03].

3.2 Motivation

In psychology, motivation can be seen basically as a basic desire behind all actions of human beings [Maslow, '43]. Motivation is considerably based on emotions, which includes the search for positive emotional experiences (subsequently avoidance of negative experiences), where positive and negative are defined individually. “Motivation generally refers to start, control and uphold physical and psychic activities” is a possible general definition for motivation, which can be found in many textbooks [Gagne, '65], [Wilson, '74], [Logan, '81], [Holzinger, '02b]. De Charms (1976) [de Charms, '76] summarizes the ideas behind motivation in a short sentence: “Motivation is a moderate form of obsession”. However, what definition we follow, it is of no question, that motivation is of vital importance for learning. We followed the model that motivation is dependent of the person (motive) and the situation (incentives) and this directly causes alterations in the person's behavior (cf. also with Zimbardo [Zimbardo and Gerrig, '99]). Motivation is also extremely important for self-regulated learning [Wolters, '98].

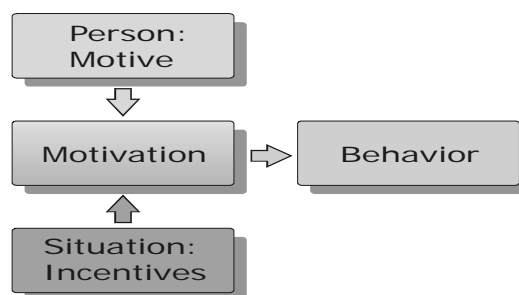


Figure 3: Motivation in a common definition

Due to the fact that within our experimental setting we measured motivation through indicators in behavior and attitude; we defined these indicators as motivation variables [Zimbardo and Gerrig, '99].

These variables show the existence of a motive and provide information about its correlating strength. For the case study with "TRIANGLE" the connection between motivation and the effects of multimedia was of specific interest.

Generally, in connection with educational software, two central questions emerged within the design and development of our software:

- Can this multimedia educational software increase motivation for learning?
- Is an apparent increase in motivation caused only by a moment of curiosity, or will the use of our multimedia educational software permanently maintain a higher level of motivation?

Whilst the second question can best be answered by a long time study, the case study with TRIANGLE can easily provide an answer to question 1.

To gain a better understanding of our experiments, let us introduce a further theory: According to Brehm & Self (1989), [Brehm, '89] the intensity of motivation is reflected by changes in the sympathetic nervous system. Consequently, increasing motivation is dependent on increasing arousal [Duffy, '57]. This known psychological concept refers to the degree of alertness, awareness, vigilance, or wakefulness and varies from very low values (coma or sleep) to very high values (panic or extreme anxiety); however the relationship between arousal and intensity of motivation is not linear.

This relationship is known as the Yerkes-Dodson-Law, first described by Yerkes and Dodson (1908). The law points out that there is an *optimal level of arousal* for gaining the most effective learning behavior [Yerkes, '08], [Holzinger, '02b]. Consequently, the expectation of our concept is to maintain an optimal level of arousal amongst the end-users in order to achieve the best learning performance. Berlyne (1965), [Berlyne, '65] pointed out, that some of the most important sources of arousal are stimulation, meaningfulness, and for us particularly relevant, the *novelty of situations*, and the surprises (or surprising situations) that come along with them.

A further interesting cognitive factor is also described by Brehm & Self (1989), [Brehm and Self, '89]: Motivational arousal may be a function of the extent to which the learner assumes *personal responsibility* for the outcomes of behavior. Subsequently, that is directly connected with something we call the "Tamagotchi-Effect" (see section 3.4).

3.3 Incidental Learning

3.3.1 Two Real Life Examples to explain incidental learning

To gain a better understanding the meaning of the term "incidental learning" is best described by taking two examples of real-life:

1) Searching for information in the internet. Using a search engine to get information on a certain topic will seldom provide hits including 100% satisfying results. However, the end-user must still browse through a bundle of pages, in order to collect chunks of desired information. This obviously can be described by intentional learning. However, on every page the end-user finds information chunks he did not intend to perceive, but in order for the search for the desired information the end-user also must check at least some of the information chunks consume those chunks – unintentionally learning some of the viewed chunks, consequently incidental learning has happened.

2) Another example is watching one of those very popular game shows on television mentioned in the introduction. The people watching (independent of age, profession, background etc.), are very concentrated to the action on the screen by various moments of motivation. Certainly, they will try to guess, what could be the correct answer and the correct answer in becoming very important momentarily. Although it is not of serious importance if they succeed in finding a correct answer; in any case this situation causes thinking and ... incidental learning!

3.3.2 Theories and the integration of the theories into TRIANGLE

As the examples in section 3.3.1 clearly demonstrated not all learning is intentional and unplanned learning is often not noticed. However, in traditional classroom settings as well as in traditional computer-assisted learning sessions intentional learning dominates. Learning models based for instance on game shows are an ideal example of a challenge in the integration of new psychological concepts into software [Wang, '97], [Lieberman, '98]. Similarly, by concentrating on the actual goal of winning, or at least on achieving a good score, participants learn a lot of facts, especially when they come upon a question they do not know. The first attempt will try to combine known facts to the correct answer (constructivism!). The participants' attention is focused on the current problem and the correct answer (provided either by the participant or a quiz master) will be memorized – a learning process occurs as a result. Though there are several definitions of incidental learning, most of them coincide closely to the following definition cited in [Lankard, '95]: "Incidental learning is defined as a spontaneous action or transaction, the intention of which is task accomplishment, but which serendipitously increases particular knowledge, skills, or understanding. Incidental learning, then, includes such things as learning from mistakes, learning by doing, learning through net-working, learning from a series of interpersonal experiments".

Consequently, incidental learning, sometimes also called implicit learning [Seeger, '94], can be seen as a very important resource in human learning and motivation [Rieber, '91]. It is obvious that incidental learning is particularly effective for

children. Certainly nobody would deny that children up to the age of six learn lot - their mother tongue for instance. In current education models, however, incidental learning has lost its importance and has been replaced by a “sit down, listen and repeat” approach [Anderson, '95]. Among other things, TRIANGLE is an attempt to utilize principles of incidental learning. This is done by linking related facts to an information mainstream organized in small hypertext portions. The success of the learning process is tested in a game show. Mastering the game show is the primary goal for the students who play TRIANGLE as a game rather than use it as an educational tool. Standard research experiments in these fields include examples such as done by Anderson & Bower (1972) [Anderson, '72], where one group of the testing persons was informed that afterwards there would be a memory test, and the other group was not: In this study the intentional group recalled only 48.9 % of the sentences while the incidental group recalled with 56.1 %, significantly more. Interviews later on showed that the intentional learners performed less well because many of them were busy employing poor memorization strategies, like saying the sentence over and over again to themselves. Anderson & Bower (1972) subsumed that many learners are hampered in intentional learning situations by their mistaken ideas about memory and memorization strategies.

3.4 Tamagotchi-Effect

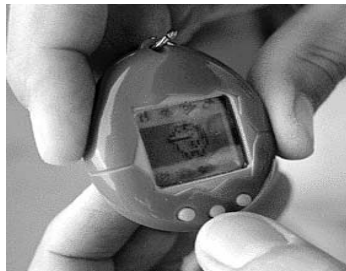


Figure 4: The classic "Tamagotchi"

In 1996 the Bandai Company introduced the Tamagotchi toy [Bandai, '02]. The name derives from the Japanese words "tamago" and "chi" which can be translated as "egg timer". By February 1997 about 700,000 units had been sold alone in Japan - without any advertising by Bandai. From 1997 onwards the “cyber eggs” were available worldwide and the toys became one of the greatest success stories ever [Horikoshi, '97]. The Tamagotchi success was accompanied by a growing debate on the influence of such toys on children.

The idea behind the Tamagotchi and successors was the *construction of a relationship* between a virtual pet and its owner. As a very simplified model of real life the owner is responsible for the well-being of the virtual creature. His or her actions and their consequences are the subject of a game; in some way he/she gains power over another creature. The advantages and disadvantages of using these toys is questionable,

however, the most interesting aspect in terms of educational software is the strong relationship between a human being and a lifeless “object”.

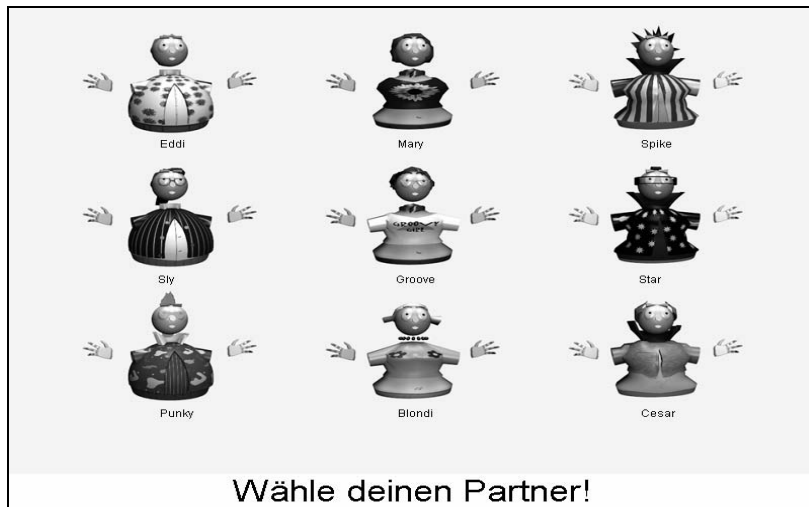


Figure 5: Virtual companions (Choose your partner!)

The core idea was to explore if it is possible to develop a similar relationship between a learning software and its end-user and what increase of motivation and, even more important, what success in learning could be achieved. This Tamagotchi-Effect could also be useful in other areas, for example in medical training: For example, if a student of medicine dutifully looks after a virtual diabetic, it will thrive and the disease will be well controlled, or else the virtual patient deteriorates in accelerated time. This allows a safe experimentation and promotes awareness of the importance of self care in the management of chronic illnesses [Loke, '98].

However, to carefully investigate this effect in TRIANGLE we implemented a kind of “personal assistant” (avatar), working together with the end-users. This assistant (or rather “partner”) behaves in a similar way to the original “Tamagotchi” described above. The idea behind this kind of virtual partner is to build the strongest possible relationship between the end-user and the learning software, optimistically increasing the learning success.

It was also obvious, that young people tend to have a personal relationship to toys and favorite gadgets (e.g. mobile phones are personalized). If it is possible “to bind” a student to learning software this can be utilized in many ways.

4 Technological Background

Before creating the prototype, some methods had to be considered for implementing the three main hypotheses to be proven in TRIANGLE, consequently that reliable results showing positive or negative effects could be retrieved in our planned experiments.

4.1 Technological Implementation of “Motivation”

As described in section 3.2 the notion of motivation in general is very comprehensive. In order to use TRIANGLE as a tool to assess motivation for computer based learning we carefully thought about the design issues. We decided to develop it as a game show (or a quiz game) by making use of modern multimedia effects in order to achieve a high level of motivation amongst our targeted (young) end-users. Graphics and “rocking” sound “disguise” the learning software as an awesome game, instead as an electronic school book. The basic idea behind the game show concept was to utilize the obvious addiction to every kind of quiz show which can currently be found among people of any age.

4.2 Incidental Learning

As explained in section 3.3.1 before the internet and game shows are very good examples for the idea of incidental learning, consequently there are two ways in which TRIANGLE serves as a test bed:

- In TRIANGLE, related information is linked to mathematical facts and formulas in order to find out how much can be learned incidentally;
- The number of possible questions in the game show is limited. There are three "topics" – mathematical knowledge, funny questions and related facts. The probability for questions to reoccur in a second attempt of the game show is 50% (for topic 1 and 3). Subsequently, if (incidental) learning occurs either through success or failure in a game show, the score had to improve!

4.3 Tamagotchi Effect

In order to investigate the so called “Tamagotchi Effect”, some kind of virtual puppet had to be created which interacts with the end-user, building a relationship (a kind of partnership) between the computer creature and the human being in front of the screen. Such a strong relationship can be used to provide valuable hints, to emphasize certain topics and more. Although experience in the development of Intelligent Tutorial Systems was available [Holzinger, '00], unfortunately, due to time restrictions within this project, we could not implement a high-level logic as it would be necessary. However, misuse and misinterpretation of the term “Intelligence” and in particular “Artificial Intelligence” has made it increasingly undesirable to label systems with this designation.

Consequently, it is generally accepted to refer to an “Intelligent Tutoring System” [Sleeman, '82], [Malone, '82] if the system is able to:

- build a more or less sophisticated model of cognitive processes;

- adapt these processes consecutively; and
- is based on these fundamentals to control an question-answer-interaction.

5 Demands on Multimedia Software for K8 learners

During the design and development of our software, there was an urgent need to explore the most important demands on learning software intended for the end-user group; both satisfying requirements of education, and to create a “state of the art” multimedia application which uses current technology. Even more important, the intention of TRIANGLE was to serve as a prototype for an easy-to-edit educational software authoring tool. This includes the necessity of a very straightforward data structure, editable even by those with average or low computer literacy.

During an intensive investigation of currently existing software for learning purposes, some basic ideas and principles of developing such software could be found. Collecting the most important principles while requesting a usable and mostly self explaining interface and a very simple data structure, a list of demands was extracted, based basically on a Learner-Centered Design approach [Soloway, '94], [Soloway, '96], [Holzinger and Motschnik-Pitrik, '05].

5.1 Attraction, Fun, Challenge, Fantasy, Curiosity

First of all, learning with computers has to be fun – multimedia elements seem to be very attractive and motivate the end-user to occupy oneself with the application. Consequently, one of the main purposes of the whole project was to find out how attractive multimedia elements can be when incorporated into learning software. We followed the principles, that the essential characteristics of good educational software can be organized into three categories: challenge, fantasy, and curiosity [Malone, '80], [Carroll, '98]. There is some evidence that these factors can enhance learning [Liebowitz, '98], [Grosshandler, '00], [Davenport, '01].

5.2 Interaction

A most important advantage of learning with computers is interaction [Ziegler, '96], [Allen, '98], [Kaur, et al., '99], [Holzinger, '02b]. Interactivity plays a crucial role in knowledge acquisition and the development of cognitive skills [Sims, '97]. However, mechanical interaction must not be confused with cognitive interaction [Norman, '86]. In classical instructional settings the teacher provides pieces of information and the student is only a more or less passive consumer, who has to transform the presented information into knowledge [Maurer, '02]. This is generally different within a multimedia application, where learners have to “dig” for the information themselves. Interactive learning (implying an active process of expanding knowledge) requires a high amount of self control, resulting in a growing ability of self education. Although this concept of self-directed learning not a clearly defined concept [Bolhuis, '03], it is generally accepted that the importance is high of such self-regulated strategies in order to enable students as early as possible to follow the principles of life long learning [Winne, '97].



Figure 6: Interactive learning, mathematics and "Godzilla" (video clip)

It is also accepted that self regulation strategies can be taught and that students who use these self regulation skills obtain better results in learning [Boekaerts, '97]. Consequently, multimedia software can support students in achieving such strategies [Biswas, '04].

5.3 Multi-Modality

Another important feature of multimedia learning environments is the multi-modality of information [Conway, '87], [Holzinger, '02a]. Making use of these features means choosing the best channel for the transportation of certain kinds of information, e.g. a video sequence for time variant processes or an animated function plot with growing variable values for visualizing a mathematical context.

5.4 Web Usage

Opportunities of collaborative learning are commonly thought as one of the most important features [Hartley, '00]. Naturally the internet structure and its communication tools support exchange of information which can be useful to construct knowledge. Therefore modern educational software should at least provide the possibility for student communication [Motschnig-Pitrik and Holzinger, '02]. However, as for the very limited time we had during this project, no internet features like multiplayer games or chat rooms were implemented in TRIANGLE, however, future versions of any similar software must implement such features!

5.5 Ease of Use

Usability – more than an buzz-word of the 21st century user interface development – is crucial for the success. The requirement that the student should not waste any time thinking about interface operations but concentrate on content necessarily leads to the

development of self-instructing user interfaces. Of course this is a difficult demand to meet; for although a whole branch of science deals with aspects of human computer interaction there is still no prototype for the "perfect interface".

5.6 Simple Data Structures

The immense speed of innovation in the computer and multimedia sector has forced companies to provide contents for their educational software. Since computer training for teachers has only got going slowly, the software developers themselves have started to fill their multi-medial presentation framework with content, at best consulting teachers or employing ex-teachers as consultants. Currently we face a situation, where teachers are increasingly integrating commercial educational software in the classes, being forced to arrange their curriculum with the given contents, rather than being able to produce multimedia-supported lessons themselves. This explains the growing network of software evaluation web-centers for teachers [Maurer, '01], [Maurer, '95], [Maurer, '98]. A universal multimedia education tool has to provide a data structure simple enough for everyone with average to poor computer knowledge to edit (or make it easy to come up with a content editor).

5.7 Hardware Aspects and Software Considerations

When sending questionnaires to the schools which offered to be test partners in this project, we realized that the different hardware equipment is a great problem in creating a homogeneous testing environment. So we decided to limit the groups of test-persons (K8-students) to 10 and let them "play" on notebooks with headsets, in order to minimize disturbing influences and to have equal conditions for every group in any school.

As the motivational aspects had precedence over public availability, and the amount of time invested in programming should not exceed the cost of testing and research of retrieved data, we decided to use a standard multimedia authoring tool. Our choice was the "Director 8" from Macromedia. Additionally this software is made for publishing in internet. The current version can easily be converted to an internet application, by making use of the "Shockwave" plug-in, which comes with most common internet browsers.

5.8 Open Architecture

Another requirement was an open architecture, which allows anybody to modify contents and examples of the learning module. In the current version this is realized by using a very simple hypertext format for the learning material and game show questions, including multimedia content organized in a strict directory and name system.

5.9 Graphics

Illustrations complementing the text and formulas are available as images. These images have to be brought on screen by clicking on a button below the text. What seems to be awkward in terms of usability is a valuable tool for user tracking. The

program counts the clicks on all buttons, representing the amount of interest in multimedia material. In a final version for use in schools, an appropriate image (if existing) should come up automatically with the text.

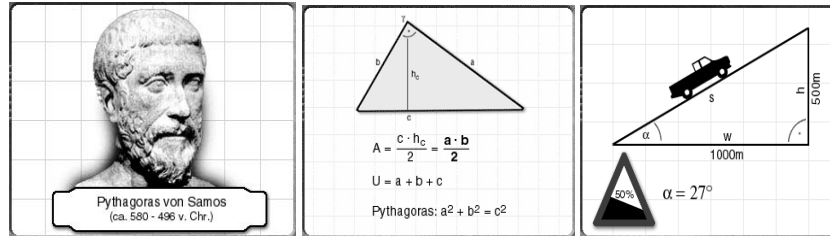


Figure 7: Various graphical objects illustrates different knowledge objects: (from left to right: a, b, c.)
a) background info, b) core formulas, c) practical application

5.10 Video Objects

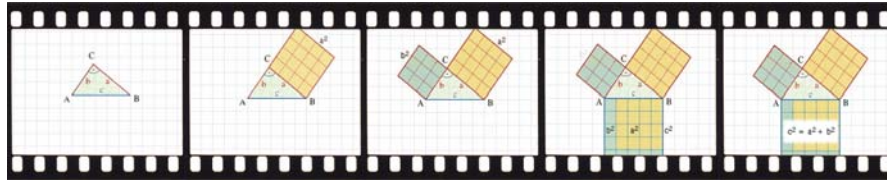


Figure 8: Video sequence explaining the geometrical interpretation of " $a^2+b^2 = c^2$ "

Video Sequences (Animations) should be used where convenient. Especially when illustrating a step by step process or demonstrating the use of a formula, animations are superior to single images. Up to date Mathematics books tend to provide “recipes” for experiments, which may help student to understand more complex formulas (including Pythagoras, Thales). Video sequences can evolve such experiments on screen.

5.11 Interactivity versus “Lost in Cyberspace”

Naturally a school book uses a serial structure for organizing contents. In a multimedia education software a more interactive approach has to be found. With the internet as a prototype for interactive associated knowledge organization, some kind of hypertext structure seemed appropriate. In guiding students away from passive consumption to self organized learning, hypertext seems to be the perfect tool for structuring knowledge in small pieces, tied together by contained references. On the other hand the phenomenon of “getting lost in cyberspace” is sufficiently documented (compare e.g. with [Otter, '00]).

If the references in a hypertext lead to too much in-depth information, students tend to lose sight of the original topic of their investigation. To avoid this – especially since the case study had to be carried out in a limited amount of time - the amount of text and layers of information were limited. At no time can the student find a path through the hypertext that leads them more than three clicks away from the starting document. Additionally, the cross references are held within the three main subjects, e.g. there is no document within Subject A leading to a document within Subject B.

6 Implementation

6.1 Motivational Factors

A multi-media application like "TRIANGLE" derives its power of attraction from the quality of the interface design and the multi-medial content. On the other hand, the interface itself has to be quite functional as it serves as a replacement for common learning environments. While learning, the player deals with a text area ("the book"), a multimedia content window ("the blackboard") and some navigational elements. The virtual companion also has a very prominent place on the screen and is always present and in motion.

The training phase could bore some students, so the avatar (the learning partner) comes up with witty comments, creating a moment of motivation to continue learning in order to see all the funny comments. The primary motivational element is the game show. Here the player can show what he has learned and win points by answering correct questions. Thus the training appears to be only preparation for the game show, while in reality it is the main purpose of the whole module. In addition to the multi-medial components of the interface, animated jingles introduce the player to the phases of the game. Music is not a carrying element throughout the program; nevertheless, it fills the game show with ambience.

6.2 Incidental Learning

One of the main theses to be tested with "TRIANGLE" is the efficiency of incidental learning. The primary knowledge imparted in the game is mathematical (the content is specialized on the TRIANGLE, hence the name). However, an equal amount of additional knowledge is involved. In the training phase these two areas of knowledge are not kept separate, although internally there is a strict distinction between mathematical knowledge and additional facts, meaning that the avatar also gains only mathematical knowledge, if the player only retrieves pages with primary content.

6.3 Tamagotchi Effect



Figure 9: Avatar, prerendered animations sequences

The virtual companion is implemented as a sequence of pre-rendered video files. In the training phase, the avatar rests on the lower right side of the screen, reading in a book, looking around, talking to the player and reacting to screen changes. This is implemented by an event driven system. At every event occurrence a video sequence is added to a animation queue. For greater diversity there are up to three different video sequences for the same event. This avoids repetitions and makes the avatar more "alive". In the game show the chosen avatar is one of three candidates playing. Depending on the correctness of the answer it is delighted or sad.

The most important fact about the Tamagotchi, however, is the ability to learn with the player and to help in the game show. This is implemented in a very simple, but effective manner.

A routine calculates the time required for reading the whole page, based on the number of words, after about 70% of this time has passed without a change to another page, the avatar "learns" this part of the material. This simple algorithm is sufficient for a case study but for a permanent use of the software it had to be replaced by more complex – maybe AI driven – routines. Depending on how much the avatar has learned, it can answer questions for the player in the game show. It is up to the player how much time they wish to invest in training the avatar; thus the avatar itself is the learner's personal "Tamagotchi".

6.4 Runtime Evaluation

Since TRIANGLE was originally intended to serve as a test bed, in this version, the software has to fulfill some tasks beyond the game functionality itself. End-user data is collected from the beginning and some values are calculated from the way the end-user handles this software.

Most of the end-user data is gained by purely increasing counter variables on end-user input or storing the value for a end-user decision. Some of these variables include:

- Number of avatar chosen;
- Number of hyperlinks followed;
- Number of correctly answered questions (topic x, round y);
- How often did the avatar answer for the specific end-user?

Some values represent the time the end-user spent for some phases of the program, e.g. the time in the learning phase, which is calculated when using the 'exit' button to quit the learning phase and go straight to the game show.

A special set of values stored the "percentage learned of topic n". Possible values for n are 1 (mathematical knowledge) and 3 (related facts), topic 2 is reserved for "silly questions" in the game show. Some hypertext files may have topic 0; e.g. menus or other text which does not really contain valuable information.

Consequently, our software had to check how many of an overall number of $p(n)$ hypertext files of a topic n were indeed learned. This is done by adding the current text to a list of learned material (e.g. learned(n), where n represents the topic) whenever it was learned. To check whether a given chunk of hypertext can be considered as learned is a little more complex than just measuring time.

First the amount of time is calculated, which has to pass before it can be assumed that the user has really consumed the hypertext. To do so, a special routine "text2time(text)" calculates a value which represents the time required for reading that text. This is done by simply counting words and characters resulting in an average word length. This value is then multiplied with a factor F, which was gained in a series of experiments.

6.5 Open Architecture

An open architecture for the content data structure was a basic requirement. TRIANGLE is a prototype of learning software that provides multi-medial fun and edutainment capabilities while being open to everyone who wishes to impart any kind of knowledge to students. Therefore a very simple hypertext format was developed. There are two types of hypertext: content and examples, both in plain text format and divided in sections initiated by defined tags. The examples contain the question title, the question, the correct answer and the maximum points. Content consists of a header, any numbered tags and the information itself. In the text, hyperlinks can be set by formatting a word in a certain structure.

The target of a hyperlink is simply the filename of another text file, similar to HTML. In addition multimedia content can be provided by tags linked to bitmaps or video files in the corresponding directories, and also the witty comments of the avatar are defined in the content hypertext files. Considering this simple data structure, one can see that it would be easy to provide a simple content editor for anyone who would like to adapt the module for their learning material.

7 Experimental Setting

7.1 Target Group

TRIANGLE was tested in two schools in Austria of different types, the Hauptschule Mariapfarr and the Bundesgymnasium Tamsweg. The case study was supported by a mathematics teacher (one at each school), who selected 22 students, taking care to find a balanced test group regarding gender, mathematics knowledge etc.; of course a prerequisite for the case study was the consent of the headmasters from both schools, however, both were very interested in this project and provided a separate classroom for the tests, making an optimal setting possible. In cooperation with the teachers, two groups of 11 students were selected at each school. The first group tested a version of TRIANGLE without the avatar – the other group tested the full version. A total of 44 students tested the software. Much attention was paid to the variety of the students, e.g. different sex, varying mathematics and computer knowledge. There were a couple of reasons for the choice of include K8 students into our investigations. The students were aged between 14 and 16 and they already had some experience in using computers. The mathematics curriculum is independent of the school type, which made it possible to test the module without the necessity of producing various versions with different contents. Mathematics was chosen because it is rarely the favorite subject of students at this age, therefore it is ideal for testing motivational factors [Brehm and Self, '89, Holzinger, '97].

Table 1: The test groups

Group	Description	N=44
Test group A	Students with avatar class 1	11
Control group B	Students without avatar class 1	11
Test group C	Students with avatar class 2	11
Control group D	Students without avatar class 2	11

7.2 Classroom Settings

In both schools the setting was very similar. A special room was adapted for the test. Every student had their own table with a notebook computer, equipped with an external mouse and headphones. In addition, every student had enough space to fill out the questionnaires. Two assistants were seated in front of the students and lead them through the test procedure. Explanations were supported by transparencies. Groups of ten students were placed in a classroom each equipped with a notebook computer. The first questionnaire collected data about motivation, mood, readiness etc. Then the students played the learning module in a time limited (20 minutes) training process, in which the students were allowed two attempts to win the game show with a maximum of points. During the game, the software collected data about the user behavior. Afterwards, another questionnaire dealt with the students'

enjoyment when playing the game (and learning). Finally a questionnaire collected general data.

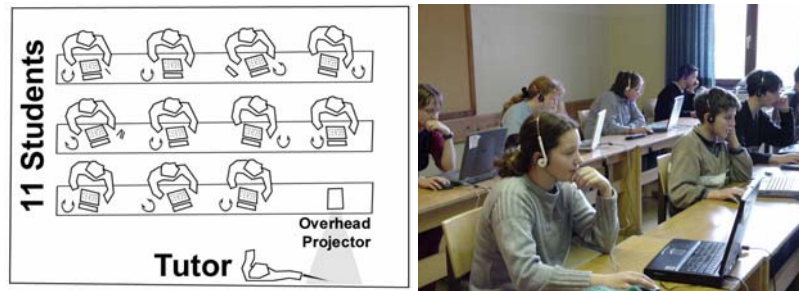


Figure 10: Experimental setting: sketch and shot from testing

Five questionnaires and an in-game user tracking were used to retrieve data on the three basic questions. For reasons of conformity, the in-game user tracking is treated like questionnaire number two in the following report. Questionnaires 1 and 3 dealt with motivation. In the first questionnaire, motivation for performance is tested. The analysis of the retrieved data returns values for the “hope for success”, “fear of failure” and the difference between these two values - the “resulting hope”. This first questionnaire returns a certain level of motivation of each student. Questionnaire 3 (immediately after playing the game) returns a similar value which can be compared with the previous values and gives information about a possible rise of motivation after playing the game show. Finally Questionnaires 4 to 6 collect some data about the student’s attitude towards mathematics, computer experience, primary computer usage and general demographic data.

Table 2: Test schedule and Questionnaires

Test Schedule	Retrieved Data
Questionnaire 1	motivation test using the AMS scale (c.f. [Chiu, '97], [Rheinberg, '97], [Gjesme, '70]).
User Tracking (“Questionnaire 2”)	testing incidental learning by analyzing the generated logfiles
Questionnaire 3	motivation after playing the game
Questionnaire 4	students attitude towards mathematics
Questionnaire 5	computer experience, user profile
Questionnaire 6	demographic data

We also implemented a built-in user tracking mechanism for retrieving data while the test persons are playing. In this way results do not depend only on individual

statements but objective data is retrieved about the way the students use the program and consume its content. The following flow chart shows the program flow of TRIANGLE and the table lists all data retrieved in the different phases. After finishing the game, a small log file is saved to the hard disk which holds all values in a comma delimited format.

7.3 Program flow

The Program flow can be divided into 5 significant phases:

1. Login / Tutorial
2. Demo Game Show
3. Training
4. Game Show
5. Score / Exit

The test group gets the first password, bringing on screen a series of screen shots used by the assistant to explain the game rules and the handling (navigation elements, game rules, time limits). There are two different passwords, one calling up a tutorial for the version without the avatar, the other one the full version. Depending on the second password given, either the version without avatar or the full version is started. First a demonstration game show with 3 simple questions makes the user familiar with the game rules, time limits, scoring system, the game idea itself and of course this prospect of the final game should produce a push of motivation for the training phase. The third phase is the actual learning tool.

As described in the previous chapters the students use a simplified hypertext browser to learn as many facts as possible for the forthcoming game show. In the full version the avatar comments on the text and makes jokes when talking to the user. Students can exit the training phase with an "Exit" button, but there is no chance to come back later. After 20 minutes the training phase ends automatically. The fourth phase is the game show. Every student has two attempts to achieve a maximum score. Every question is worth a certain amount of points (defined in the corresponding text file), after a calculated time period points start to count down to one, from this moment on the two opponents may answer the question instead of the player. Wrong answers are "punished" by reducing the score (minus 20 points).

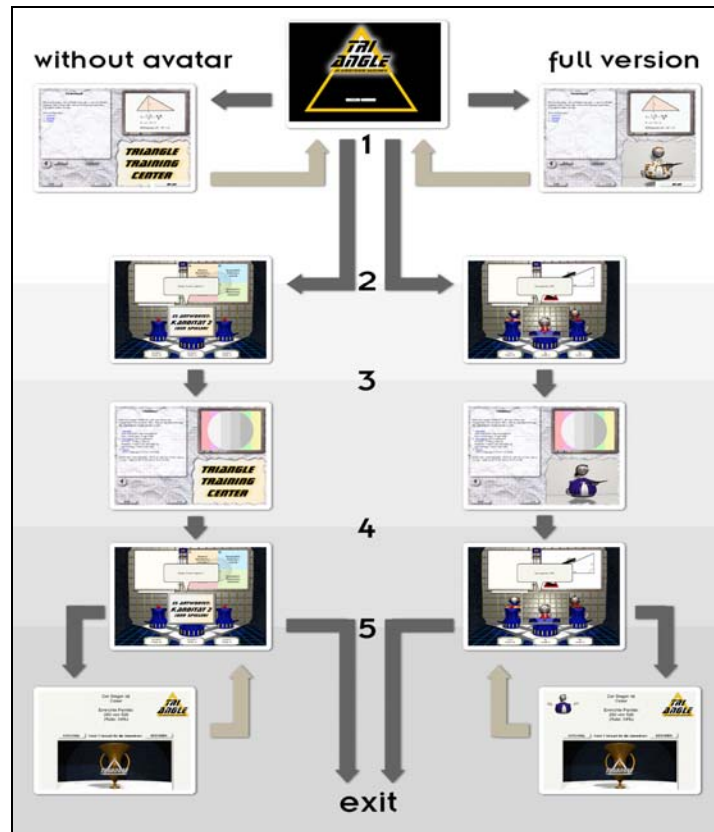


Figure 11: Program flow

The end screen shows the final score as absolute points and percentage value (percent of questions answered correctly). When the participant has finished the first round of the game show they can now select to try again or exit the program. This selection is a measurement of how much the user liked playing the game. The program does not exit to the desktop but shows a “Thank You and Good Bye”. Subsequently, the students were prevented from interfering with the note-book installation.

7.4 Data Provided by the Software

As mentioned before, the software itself collected a variety of data, some for reasons of user interface testing, others required for motivation tests. The program saved the data to an external file which was easily transferred to a statistical program (SPSS).

The collected data contained:

- the chosen avatar,
- the number of correctly answered questions (divided into mathematical and additional knowledge),

- the intensity of content study (by measuring time in relation to the amount of text on a page), and
- the number of hyperlinks followed, pictures viewed etc.

Most of this data was used to control questionnaire results.

8 Findings and Discussion

The first questionnaire measured the motivation according to the School Achievement Motivation Scale [Chiu, '97], which has its roots in the AMS-Scale developed by Gjesme & Nygaard (1970) [Gjesme and Nygard, '70]. The first 15 items determined the performance of motivation (expectation and success). The remaining items measured the unsuccessfulness and fear. Thus, the first questionnaire showed the level of motivation before starting TRIANGLE. Our program delivered the values during the game by storing all links used in log-files.

The second questionnaire set, after playing with TRIANGLE, delivered a standard of comparison to the first test. Finally, a special test showed the adjustment in attitude to mathematics in school.

8.1 Motivation

A high level of motivation is often a prerequisite for success. There is a high probability that learning will be without success if there is a lack of motivation. Therefore we needed to measure the motivation of the students to correctly interpret the results retrieved through the other questionnaires. Without testing the motivation before and after playing the game, there would be no chance to value the influence of the avatar.

8.1.1 Questionnaire 1 - Motivation before testing the software

The first 15 questions deal with various aspects of motivation; the next 15 questions are the exact counterpart. For every question the student has to provide a level of agreement. We classified a student as "highly motivated", if they perchance exactly agree (2) to 6 or more of the first 15 given statements. Variables 16-30 are control variables to prove the results of the analysis of the questions 1-15 in producing exactly contrary values. Unfortunately the results did not correspond. Normally the distribution of students who answered with "exactly right" (var. 1-15) and "not at all" (var. 16-30) should approximately match. The diagram visualizes the results and helps in comparing.

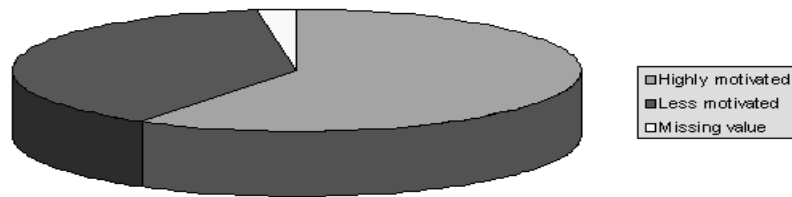


Figure 12: Evaluating motivation of students

8.1.2 Questionnaire 3 - motivation afterwards / feedback

Questionnaire 3 was given to the students immediately after they had played TRIANGLE. Results of this analysis can be seen as feedback on one hand, and on the other hand as information about difficulties in using the computer was collected. The first question (31) was if the students believed that contents were imparted in a better way than through books or other classical education media. 81.8% agreed. Considering the fact that only a very small part of the entire learning material for a mathematics curriculum was available in the program, this result must be interpreted as evidence of high motivation to use the software. A combined analysis of the next six variables proved this assumption. Questions 32 to 37 get feedback about general enjoyment of playing with the program. A student is said to like using the program if 3 or more out of 6 questions are answered with “exactly right”. A resulting amount of 65.9% of the students liked using TRIANGLE. In order to understand reasons for a possible dislike of the program, the next six questions dealt with a variety of problems when using the PC and learning software. 81.2% of the students agreed to none of the six statements (2) about possible problems and therefore felt comfortable with learning on the PC.

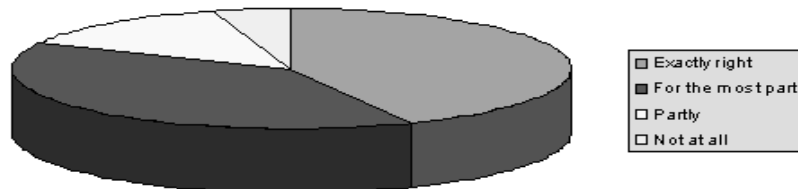


Figure 13: Motivation afterwards, feedback

In addition we wanted to know how students rated the difficulty level of the game show questions. This time 50% of the students found that some of the questions were too difficult. As a game needs to be challenging but not frustrating, this result is very satisfying for valuing the content quality.

8.2 Runtime Evaluation

Two variables saved during runtime value the student’s motivation. On the one hand, the time spent on learning tells about motivation before the game show (including a

possible motivational effect caused by the demo game show), and on the other hand the number of game show rounds (max. two). With a 20-minute time limit given, the majority of the students spent more than 10 minutes in the training part, 40.9% used more than 75% of the available time (15 to 20 minutes). Only two students were not motivated enough to try a second game show round, all the others made another attempt after finishing the first round.

Another variable of interest is the acceptance of the multimedia elements. There were 31 different elements (pictures, video clips and formulas) available through media buttons during the training session. Every time a student pushed one of these buttons, an internal counter was increased, measuring an amount of interest in percent (compared to 100% - every media element is watched once) There were rates up to 160 percent, meaning that some elements were brought on screen more than once. As described later there is a significantly higher rate of success in the game show for students who had a higher consumption of the media elements.

8.3 Incidental Learning

In order to test the effect of incidental learning, we first compared the percentage of learned facts in the training phase with the correct answers to corresponding questions in the game show for both of the subjects 1 and 3. As mentioned before the learning material is made up of mathematics knowledge (subject 1) and supplementary facts (subject 3). While good mathematics students will be able to answer questions based on subject 1 without having learned during the training phase, they have to learn the supplementing facts to master 4 of the 10 questions in the game show.

The number of correct answers for subject 1 questions is widely independent of the time the students spend in reading the mathematical information. As all questions are designed so that they can be answered within 10 - 30 seconds without the use of an electronic calculator, a dependency between the students' mental arithmetic capability and the success in the game show could be expected.

In questionnaire 4 we ask for the participants self estimation of their mental arithmetic capabilities - and indeed there is a significant correlation between this variable and the number of correct answers for subject 1 type questions.

A very different behavior shows the analysis of subject 3. A significant correlation between the amount of learned supplementary facts (subject 3) and the correct answers (relating to subject 3) can be found. So while the answers to subject 1 type questions can be simply calculated by a witty student, the answers to subject 3 type questions can only be correct if some of the facts integrated into the hypertext chunks were memorized.

Incidental learning also occurs when playing the game show. Altogether there are only a limited number of questions so that on average two of four questions will be repeated in the second game show round. Better results in the second attempt imply a learning effect. Indeed the scores improved when playing the game show a second time. So the students learned by failure - whether they planned to do so or not!

8.3.1 Runtime Evaluation / Questionnaire 4

The analysis of the correlation between the percentage of learned material and the correct answers in the game show - both made separately for each subject - confirm our theory. There is no dependency of correct answers (relating to subject 1) on the amount of learned mathematics knowledge.

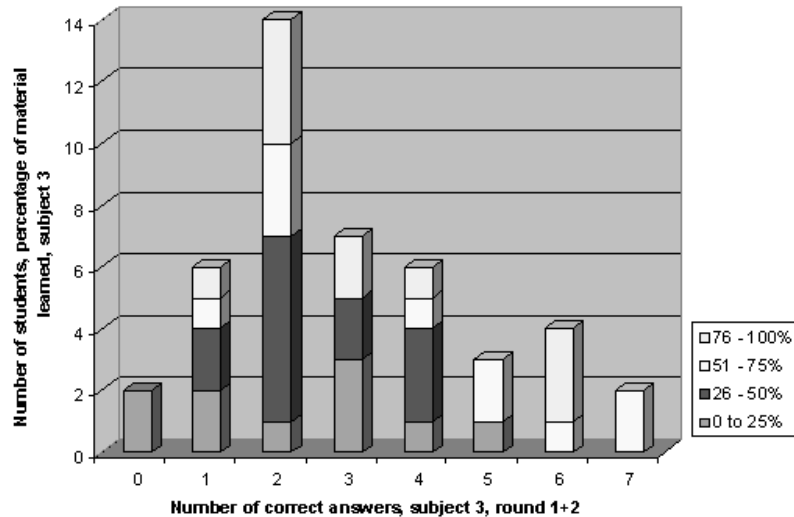


Figure 14: Correlation - learned supplementary facts / correct answers

The number of correct answers is widely independent of the time the students spend in reading the mathematical information. As we designed all the questions so that they can be answered within 10 - 30 seconds without the use of an electronic calculator, we assumed that there may be a dependency between the student's mental arithmetic capability and the number of correct answers. In questionnaire 4 variable 48a holds the participants self estimation of their mental arithmetic capabilities - and indeed there is a significant correlation between this variable and the number of correct answers.

A very different behavior shows the analysis of subject 3. A significant correlation between the amounts of learned supplementary facts (subject 3) and the correct answers (relating to subject 3) can be found. Incidental learning also occurs when playing the game show. Altogether there are only a limited number of questions so that on average two of four questions will be repeated in the second game show round. Better results in the second attempt imply a learning effect. Most students improved their results in the second attempt.

8.4 Tamagotchi Effect

To decide whether the presence of the avatar had a positive effect on the learning success or at least caused an increase in motivation, there were two groups, one group tested the program in a version without avatar, the other one tested the full version. The following analysis takes a closer look at possible differences between these groups as well as at the sympathy for the virtual friend.

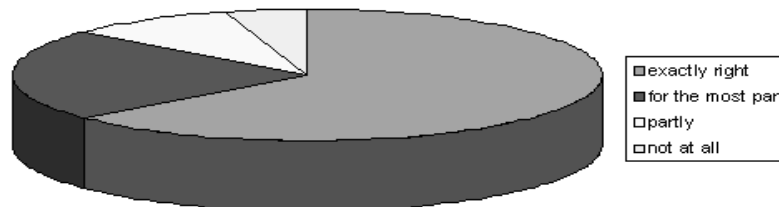


Figure 15: Tamagotchi effect

The group playing the full version was asked about the attraction of the virtual partner. Most of the students liked interacting with their avatar.

There was no difference between the groups concerning the question whether they liked playing the program in general. No positive effect of the avatar was detected. Students who answered three or more of the questions 33-37 with “exactly right” can be rated as “having fun playing the program”.

In general, there was no significant correlation between the existence of the avatar in the game and the measured motivation of the students.

8.5 Runtime Evaluation

Analyzing the saved log files we focused on the possible effects of the avatar on success in the game show, as well as motivation for a longer training phase, because the avatar created a more relaxed atmosphere in the training session. First, the existence of the avatar was of no relevance for the time spent in the training phase. There is no correlation between playing the full version and the duration of the training phase.

The group playing without the avatar also did not show significantly different results in the game show from that of the group who tested the full version. In the full version, students had the opportunity to let the avatar answer game show questions for them. The probability for a correct answer depended on the amount of learned material in the training phase (calculated separately for each subject).

9 Conclusion

9.1 Motivation

The case study showed a high level of basic motivation among the students using TRIANGLE. Whether due to real interest in the program or the novelty of something new is difficult to judge: video observations showed that most students enjoyed the game. Several students reacted emotionally to success and failure, showing that they were really *into the game*. These motivational factors can be used to intensify previously learned material. Multimedia elements received a high level of acceptance. The presentation was more detailed and the educational method of game-based learning showed a clear advantage over traditional education media such as blackboard teaching or textbooks and standard methods. Furthermore a correlation between the exposure to media elements and correct answers in the game proves the commonly accepted advantage of multimedia education software.

9.2 Incidental Learning

The results of the case study showed that associated facts are indeed memorized. By connecting to learning material via hyperlinks, a large amount of additional knowledge can be imparted. Supported by carefully selected multimedia elements, which may serve as *anchor points* (the re-appearance of the images in the game may have helped some students to remember certain facts) the learner builds a network of facts - a kind of mind map of the knowledge the hypertext contained. Since there was very little probability that the students were acquainted with the material before their participation, the relationship between learned material and correctly answered questions serves as proof for the success of incidental learning. In addition, another process of *unintentional* learning occurred when playing the game. As almost every participant was able to improve their game score in the second round, and since a minimum of two questions from the first round re-appeared, learning could be shown to have taken place.

9.3 Tamagotchi-Effect

While the students liked to interact with the virtual partner in the program, no positive effects of this interaction could be measured. There were no significant differences in the motivation and success of the two groups using different versions of TRIANGLE. A few explanations for these facts present themselves: First of all, the general motivation was very high and the avatar, or its absence, did not have any observable influence. The group that played a version without their virtual partner expressed liking for the program to the same extent as the other group. Maybe different results would have been achieved by letting each group play both versions, since then they would have had a comparison. Mainly for technical reasons, the interaction between the avatar and the player was based on a very low level of artificial intelligence. Therefore the moment of personalization was not as strong as initially planned.

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