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Better Results in Mathematics Lessons with a Virtual Personal Teacher

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ABSTRACT

In this paper we present the results of an experiment made with our e-librarian service "MatES", an e-Learning tool on fractions in mathematics. MatES allows students to enter complete questions in natural language and returns semantically pertinent multimedia results which explain the answer to the users' question.

The efficiency of MatES was proven by benchmark tests. From 229 different user questions, the system returned the right answer for 97% of the questions, and only one answer (the best one) for nearly half of the questions.

A class of 22 students took part in the five week experiment. Students were autonomous and learned through exploratory exercises. Students asked MatES questions. The multimedia explanations yielded by MatES allowed to acquire new knowledge, and to complete the exercises.

At the conclusion of the experiment, MatES was confirmed as an efficient e-librarian service that can be used in school or at home. It can be used in blended learning, distance learning, and collaborative learning situations. The students used MatES as a tool that helps them to do better in mathematics. We measured relevant improvements in the students' school results over the period they used MatES, compared to the school results before they used MatES. One of the main reasons for this excellent result may be that the students were more motivated, and therefore put more effort into learning and acquiring new knowledge. The students also stated that MatES explained better, and that they understood the course content more easily.

Categories and Subject Descriptors

H.3.7 [**Information Storage and Retrieval**]: Digital Libraries; G.4 [**Mathematical Software**]: User Interfaces; K.3.1 [**Computers and Education**]: Computer Uses in Education—*Computer-Assisted Instruction*

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General Terms

Measurement, Performance, Reliability

Keywords

Autonomous and exploratory learning, school results, multimedia knowledge base

1. INTRODUCTION

In this paper we show that e-Learning can improve school results. We present the results of an experiment that we made in a school with "MatES", an e-Learning tool about fractions in mathematics. This tool understands students' complete questions in natural language, and returns only few but semantically relevant results in a multimedia form. There was no classical lesson—i.e. teacher centered lesson—during five weeks where the teacher gave explanations, but the students had to learn in an autonomous and exploratory way. They had to ask questions to MatES just the way they would if there was a human teacher.

Our hypothesis was that this different training approach (where each student is active in the learning process and plays the role of an explorer) would result in higher motivation and produce students who are willing to put more effort into learning mathematics. Furthermore, it was to be investigated if the simple multimedia presentations would be complete enough for the students to acquire enough knowledge to understand a certain subject without the help of the teacher.

The results of our experiment are the following. The students did not perceive MatES as a game, but as a helpful educational tool, a kind of virtual personal teacher. We measured a relevant improvement in the students' results on fractions, compared to their past results on geometry. One of the main reasons for these positive results is that the students were more motivated and therefore willing to put more effort into learning and acquiring new knowledge. The students also stated that MatES explained better and that they understood more easily. Furthermore, students always found the right answers to their questions quickly.

2. THE E-LEARNING TOOL MATES

It is known that students are better able to master, retain, and generalize new knowledge when they are actively involved in constructing that knowledge in a learning-by-

Figure 1: MatES with the question: "How to divide one fraction by another fraction?".

doing situation [10]. Teachers who have used e-Learning tools in their classes report that they changed their teaching style to allow students greater autonomy in their learning [8]. They tend to shift their style of teaching from a didactic, question-answer format to a more exploratory learning approach.

A computer tool cannot explain better than a human teacher could, but it can present information in a clearer, maybe a better way than a teacher could. Currently, students tend to be more visual learners than in previous generations because their world is rich in visual stimuli [8].

Our vision is to create an *e-librarian service*. If the student requires information about a subject (for example, how to divide a fraction by another fraction), then (s)he formulates a question to the e-librarian. The e-librarian does not have the answer to the question, but it is able to find and retrieve the most pertinent document to the student's question from its multimedia knowledge base. The student will find the requested answer in that document. The e-librarian service has the following properties:

- It fosters autonomous and exploratory learning. It allows students to ask questions in a normal and human way, by means of verbal communication.
- The system's answers are short multimedia clips. The duration of the clips is between one and four minutes.
- The system has a simple and ergonomic interface.
- It can be used independently from time and place.

MatES (*Mathematics Expert System*) [4] is a prototypical implementation of our e-librarian service on fractions in mathematics (figure 1). It was developed by the authors of this paper. It has a graphical user interface, a semantic search engine, and a multimedia knowledge base. The knowledge base is composed of 115 *clips*, which cover all important subjects on fractions as they are taught in secondary schools. The clips were recorded mainly with students. We used *tele-TASK* to create the clips.

MatES processes a question in approximately 3 to 5 seconds. The returned results are logical consequences of the inference rather than the result of keyword matchings. MatES was built to process questions in French because the mathematics lessons — in Luxembourg — are held in French.

Before using MatES in a large-scale experiment with students, we performed benchmark tests in order to measure the performance of our semantic search engine. A testing set of 229 different questions about fractions was created by a mathematics teacher, who was not involved in the development of the prototype. The teacher also indicated manually the best possible clip, as well as a list of further clips, that should be yielded as correct answer. The questions were linguistically correct, short sentences like those that students in a secondary school would ask. This benchmark test was compared with the performance of a keyword search engine over the same set of questions.

The semantic search engine answered 97% of the questions (223 out of 229) correctly, whereas the keyword search engine yielded only a correct answer in 70% of the questions

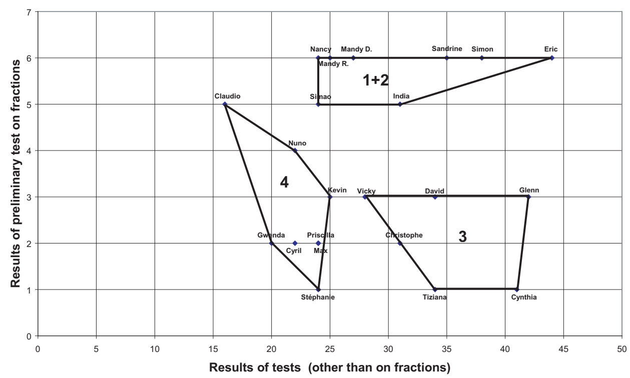


Figure 2: Average of the four tests about geometry (x-axis) and the preliminary test about fractions (y-axis) for the three clusters of students.

(161 out of 229). For 86 questions, the semantic search engine yielded just one answer, the one that was semantically speaking the best match. For 75% of the questions (170 out of 229) the semantic search engine yielded just a few results (one, two or three answers), whereas the keyword search yielded less than 4 answers for only 14% of the questions; but mostly more than 10 answers (138 questions out of 229). It is also interesting to notice that our e-librarian service always returned at least one result. This is important because we know from former experiments that students dislike getting no result at all.

3. DESCRIPTION OF THE EXPERIMENT

3.1 Generalities

Our objective is to test the advantages of our e-librarian service in a normal educational environment, and to investigate in how far this alters students' school results positively.

22 students, aged between 12 and 14 years (7^{th} grade) from the LTE took part in the experiment, which lasted 5 weeks, from February, 13^{th} 2006 until March, 16^{th} 2006. This is the normal amount of time spent on teaching fractions in this grade. All lessons took place in a computer room.

3.2 Grouping the Students in Three Clusters

In the first term of the school year (September, 18^{th} 2005 until February, 12^{th} 2006), the students learned geometry (volumes, surfaces etc.). Four class papers were written about that subject.

All students already had some basic knowledge about geometry and fractions because these subjects had already been introduced in the three previous school years. We made a preliminary test at the beginning of the experiment (February, 9^{th} 2006) to measure their current knowledge on fractions. The students were not prepared for this test.

Based on the results of this preliminary test, and the results on geometry (first term), we grouped the students in three clusters (figure 2): weak (8 students), middle (6 students) and strong (8 students). This classification helps us to evaluate our style of teaching according to three initially different levels of knowledge. We suppose that generally weak students will also have problems to learn fractions, and that strong students will also do well in fractions. We will investigate in how far using MatES will alter the configuration of the clusters.

The graphical representation that we use is based on the theory of hypervolumes [2]. For a given number of clusters (here: 3), the aim is to link the points to form convex figures (as many as there are clusters) so that the sum of the surfaces of all figures is minimized.

Figure 2 shows that there is no relation between the preliminary test and the results on geometry. Some strong students did well in the preliminary test, others not at all. Some weak students did well in the preliminary test, others not at all. This shows that their current knowledge about fractions was completely heterogenous.

3.3 The lessons before the experiment

In mathematics the teacher classically introduces a new topic on the blackboard. Then, exercises are trained together; normally one student or the teacher is on the blackboard and writes the solution. However, in our experiment there was no "theory" about fractions that was explained. We broke the "didactic contract", and employed a different pedagogy; we let the students play the role of an explorer who had to discover and to acquire new knowledge all by themselves in an autonomous way, and by using MatES as a kind of personal teacher.

In the lessons before the experiment the teacher explained her intentions to the class, and gave an example how they would work together. She explained that they would get exercises each lesson, and that they would have to find appropriate clips to watch in order to acquire the knowledge they needed to do the exercises. The students had to make the choice, which clip to watch.

The aim was to make the students understand that this kind of teaching would be more adapted to their cognitive capacities, allowing slower students to watch the same information as often as they want. Furthermore, this kind of teaching enables the teacher to guide and assist them in a more personalized way.

3.4 The first lessons

The issue of the first lessons was to figure out that it is difficult to get good information quickly, and that this is especially true with a keyword based search engine.

In the first lesson, the students learned how to formulate correct questions, because this is not easy to do for students of the 7^{th} grade. Furthermore, the teacher explained the advantages of entering complete questions in a *semantic search engine* compared to a simple keyword search. The number of results was indeed a compelling argument to use MatES; for example, the same question, "How to Simplify a fraction," in Google yielded 31400 results, whereas MatES yielded only two.

In the second lesson the students learned how to use MatES. In practical exercises they used MatES to train vocabulary on fractions. The teacher gave a sentence with a missing word, for example "We need to learn fractions because they represent...". The students' task was to formulate a question, and to find the missing word by watching the yielded clip(s), for example, "Why do we need to learn fractions?", or "What do fractions represent?".

3.5 The course of the other lessons

The course of all lessons during the experiment was the same: the students did exercises, and had to acquire the missing theory autonomously.

At the beginning of each lesson, they got a sheet with exercises to solve. Their first task was to find out what they already knew and what they did not know to solve the exercises. Then, they had to ask questions to MatES, and had to watch the yielded answers (clips) to complete their knowledge. The teacher was always present and helped if a student did not understand an explanation, or still had problems solving the exercise. Only some examples of exercises were briefly developed in class to illustrate some general mistakes or misunderstandings.

The level of difficulty of the exercises was different for the three clusters. Strong students got more advanced exercises, and weak students got very simple exercises. This allowed all the students to progress at their own pace, to be permanently occupied, and not to feel overwhelmed by the degree of difficulty of the task at hand.

The teacher reviewed all exercises at home. She marked mistakes and suggested important subjects to consider. This allowed the teacher to continuously evaluate the class and to keep a hand on the experiment (to stop it, if something turned wrong).

3.6 Course of the Tests

Two tests were written on fractions; the first in week 3, and the second in week 5 of the experiment. Both had the same type of questionnaire, and were of the same level of difficulty. The first test was more about basic subjects (for example, the representation of fractions), whereas the second one was about operations on fractions (for example, the sum of two fractions). Each test lasted two hours; one hour for a *classical test* (30 marks) and one hour for a *practical test* (30 marks). As for the first one, the test took place in a normal class room under classical conditions: no books, notes, calculator etc. were allowed. The students received a questionnaire, and had to write the solutions onto a blank sheet. The exercises were based on the knowledge they had (to have) acquired autonomously during the past lessons.

After one hour, the students moved to a computer room and continued with the second part of the test, the practical one. Each student worked individually on a computer. They received a questionnaire, and had to write the solutions onto a blank sheet. Contrary to the first part of the test, these exercises were about unknown concepts (for example, proper fractions). Therefore, the use of MatES was implicit.

Nearly all students finished both tests in time. There were also no significant complaints about the tests, regarding an exaggerated level of difficulty.

4. GENERAL RESULTS

4.1 Students' results

No significant differences could be measured between girls and boys, for either the geometry or the fraction results.

Except for two students, the class could be grouped in two clusters (figure 3): the students who did well in both tests (1 + 2), and those who had worse results in the second test (3 + 4). In general, all students did (very) well in the first test. However, the results of the second test were not

Figure 3: Results of both tests about fractions: 1^{st} test (x-axis) and 2^{nd} test (y-axis).

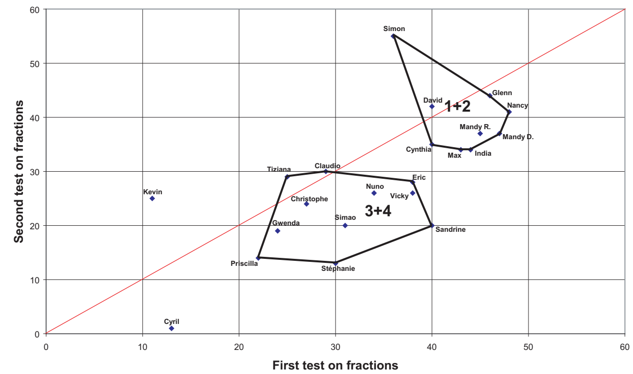
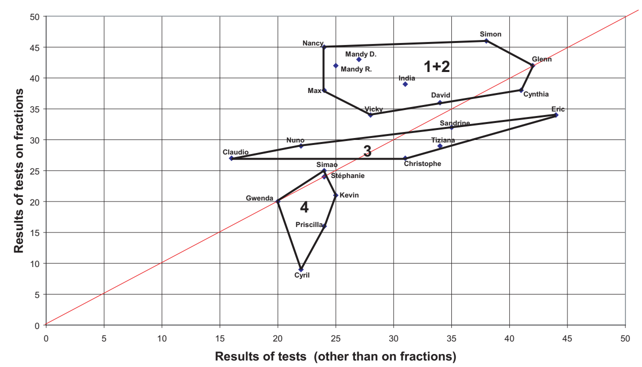


Figure 4: Average of the tests about geometry (x-axis) and the tests about fractions (y-axis).



so positive. Though, the second test was not more difficult than the first one, it took place in a time when the students had a test almost every day. This could explain the worse results in the second test.

There were also some interesting differences between the two parts of the test: the theoretical- and the practical one. The differences were not significant in the first test, but they were much stronger in the second one; the results in the practical part were better than those in the theoretical one. An explanation could be that as for the first part (the theoretical one), the students were tested on their theoretical knowledge about fractions and how well (or badly?) prepared they were for the test. But as for the second part, the exercises were about unknown concepts so that even the students who did not learn a lot for the test, could get a good result by asking questions to MatES.

A lot more revealing is the comparison of the results about fractions with the results about geometry (figure 4). We can make three general assertions: about the general results of the tests, about the changes in the clusters, and about the proximity of the clusters.

Firstly, the overall results were better on fractions (average result of the class: 32/60) than on geometry (average result of the class: 29/60), which represents an improvement of 5%. This number was confirmed by a t test of means with two paired independent samples. 11 students had better results in fractions than in geometry (they are located in the graph above the identical function). 9 of them progressed very much (at least 6 marks with a maximum of 60 marks for a test). There is even one student whose progression is 21 marks. 8 students regressed, 3 of them very much (at least 6 marks). 3 students stayed constant. In total the 11 students progressed by 111 marks against the 8 students that regressed by 50 marks.

Secondly, the composition of the clusters changed positively. Before starting the experiment, the clusters were composed like this:

Cluster	Number of students	Percentage
weak	8	36.4%
middle	6	27.3%
strong	8	36.4%

Here is the composition of the clusters at the end of the experiment:

Cluster	Number of students	Percentage
weak	6	27.3%
middle	6	27.3%
strong	10	45.5%

7 students progressed in a higher cluster with one student who progressed by 2 clusters (from cluster "weak" to cluster "strong"). 2 students regressed from cluster "strong" to cluster "middle", and 1 student regressed by 2 clusters (from cluster "strong" to cluster "weak"). The latter has nevertheless better results on fractions than on geometry. 12 students stayed in the same cluster (5 in the cluster "weak", 2 in the cluster "middle", and 5 in the cluster "strong"). Generally, the weakest students stayed weak, and strong students stayed strong. Therefore, the major changes were in the cluster "middle". Those 3 students (out of 6) that remained in the cluster "weak" generally had bad marks in all branches; they did not even maintain a correct exercise book. It seemed that they resigned completely.

Thirdly, by comparing figure 2 and figure 4 one can observe that before the experiment the knowledge of the class was generally very heterogenous. After the experiences with MatES, their knowledge became more homogenous; the difference between strong and weak students was less significant. Indeed, the dispersion graphs (figure 5) show that there exists a weak linear relation, and a polynomial adjustment. The points of these graphs are less dispersed than those of figure 2. We think that this is mainly due to the fact that the students worked autonomously and saw the sense in the activities they did.

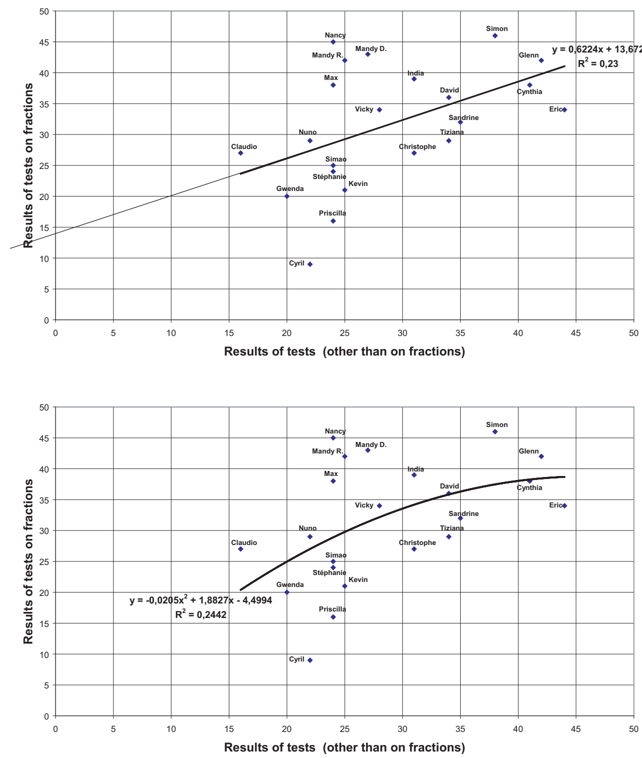
4.2 Students' Impressions

This evaluation is based on one written survey (end of week 1), weekly general discussions, and mostly one individual interview session (end of week 5).

4.2.1 Comments about this kind of learning

When asked if they think that they learned better with MatES compared to classical teaching (i.e. on geometry), 12 students (54.5%) were sure they did, 6 students (27.3%)

Figure 5: Mean of the tests on geometry (x-axis) and mean of the tests on fractions (y-axis) with (1) the regression line and (2) a polynomial adjustment.



answered somehow yes, 3 students (13.6%) said no, and 1 student (4.6%) did not know. The large majority of the students (18 out of 22) thought that their results in school could be improved with MatES.

We asked the students if they used MatES at home, supposing that they had a computer of their own (all except 2 have their own computer at home). 11 students (50%) answered "certainly", the other 11 students answered "somehow yes", and none answered "no" or somehow "no". This extreme positive result shows that the students may be convinced of the benefits of MatES. But they may also have given this answer to value their teacher's efforts in this experiment.

No real correlation can be found in the answers given to the question if they could imagine learning without a teacher. 4 students (18.1%) are convinced they could, 10 students (45.5%) said that they still somehow need a teacher, and 8 students (36.4%) answered that they still need a teacher.

Finally, they were asked if they enjoyed working with MatES. 11 students (50%) said "yes", 9 students (40.9%) said "yes, a lot", and 2 students (9.1%) said "somehow yes". None of the students disliked working with MatES. This motivation doing mathematics might be one explanation for the better school results.

4.2.2 Comments concerning MatES

Generally, MatES returned only very few results, normally one, rarely more than 3. We asked the students to give their opinion about the number of results. None of them stated that there were too few, 1 answered that there were too many, and 21 (out of 22) said that there were neither too many nor too few results.

The next question was about the quality of the search results yielded by MatES. We asked if they found the answer to their question in the results yielded by MatES. Nobody said "never" or "rarely", 1 student (4.6%) said "in half of the cases", 16 students (72.7%) said "most of the time", and 5 students (22.7%) answered "always".

One important question was about the constraint to enter complete questions. No student said that this was awkward, 7 students (31.8%) answered that they accept entering a complete question but that they did not like it, and 15 students (68.2%) answered that this was no problem at all.

We asked the students what they especially liked about MatES. 2 students (out of 22) had nothing to say. The comment most mentioned was about the quality of the search engine (10 comments): MatES yields always an answer, answers are always right and respond to the question etc. A second comment that was often made dealt with the explanations and the content of the clips (9 comments): well explained, one understands the subject better etc. Other comments were that MatES has a lot of knowledge (3 comments), that the student must not ask the teacher, and one must not wait for the teacher to be available (3 comments), that an explanation can be watched several times (3 comments), that the answers are short (1 comment), that the illustrations and explanations are presented nicely (1 comment), that one can use computers (1 comment), and that students give the explanations in the clips (1 comment).

We asked the students what they especially disliked about MatES. 7 students (out of 22) had nothing to say. The comment mentioned most was about technical problems (7 comments): the computer or MatES got stuck. Another comment that was often made dealt with the interaction with MatES (4 comments): that MatES only tolerates little errors in the questions, that one has to enter complete questions, and that it is easier to communicate with a teacher. Other comments were that the questions must be formulated in French[1] (2 comments), that the video of the presenter is disturbing (1 comment), that the system sometimes returns bad answers (1 comment), and that some explanations are too complicated (1 comment). Two students complained that it lasts too long to watch a clip to get the answer to one's questions, and that asking a real teacher or a friend would be simpler and faster.

4.3 Analysis of the Logfiles

The logfiles show that nearly all queries were well formulated. Only very little "out-of-the-topic" questions were voluntarily placed. In average, each student entered 8.5 questions per lesson (50 minutes). An average of 4 questions was asked in the lesson with the lowest number of questions, and an average of 17 questions was asked in the lesson with the highest number of questions. There was no difference concerning the number of submitted questions between an ordinary lesson and one in which they wrote a test. There was no student who entered exceptionally many, or exceptionally few questions. Weak or strong students asked approximately the same number of questions, independently of whether it was a normal lesson, or a test.

An interesting observation was that students sometimes entered the same or a previous question again. This observation is well documented in literature on surveys about how students search on the Web [1, 3]. Students tend to re-enter a previous question (or keywords) where they are sure to get a result. They often return to "landmarks" where they received good answers. We can observe that some students re-entered 3 or 4 times the same question in one lesson.

4.4 General Observations

In week 1 of the experiment, the students were astonished about the way they were able to learn fractions; that there were no classical "theoretical" lessons, and that they had to use a computer tool to ask questions in order to acquire new knowledge on their own. The fact that they had to enter complete questions was a problem during the first lessons. Firstly, entering so many words was a burden for most of the students because it demanded greater effort, and because they were accustomed to keyword based search engines (for example, Google). Secondly, at their school level, they did not yet learn how to formulate questions. Thirdly, some errors in the tool involved that MatES blocked frequently. This caused frustration, because they had to type their question again.

After the second week, all students became accustomed to this kind of teaching. Entering complete questions became generally accepted. We witnessed that most of the students entered questions very quickly. It seemed that they had a lot of experience typing on a computer (possibly by chatting on the Internet). The students also found out that formulating questions was not so difficult, because in most of the cases the instructions of the exercises were already close to the form of a question; for example, the instruction, "Simplify the following fractions" could become the question, "How do you simplify a fraction?".

With the progression of the experiment, the students became more and more amazed by this kind of learning mathematics. Some expressed that the exercises were fun, others enjoyed the video sequences and started to know by heart the names of presenters. We observed that students remembered the clips by some kind of characteristic, for example, a presenter that pronounces a certain word badly, a nice illustration inside a clip, or a presenter who explains very well. It was interesting to see that such characteristics were very useful for the students. For example, if someone had to search for a clip about the simplification of a fraction, (s)he said: "That's Lynn's clip", or "That's the clip with the pizza-example".

We were impressed by the very positive atmosphere in the classroom. Every student was occupied with her/his own exercises, and could progress in her/his own rhythm. Some worked quite fast, others were slower. All the students used headsets. It was pleasantly calm in the room. Students were allowed to communicate (except during the 2 tests). Most chats resembled these comments: "What clip did you find for this exercise?", "Did you get an answer for this exercise?", "Have you already finished this exercise?" etc.

It was unexpected that the students asked for permanent assistance from the teachers. In the first week, most of the questions were about how to use MatES, or about technical problems, i.e. the computer or MatES blocked. As for the

[1] In Luxembourg the mathematics course is held in French, which is the second foreign language.

other weeks, the kind of questions changed rapidly in a more mathematical context. Questions resembled to these ones: "I don't understand how to solve this exercise, please help me!", "Last year we did not do it like that.", "Is it OK if I write it in this way?" etc. In fact, students were not used to working individually and autonomously, especially not in a mathematics course. Hence, students were often unsure if they understood correctly, or if their solution was right.

At the end of week 5, students were sad that the experiment was over, and that they returned to a "classical" kind of learning. Several students asked to get a copy of MatES for their personal use at home.

5. DISCUSSIONS

In this section we analyze the data from the experiment (section 4), and try to figure out if the better results can be traced back to the use of MatES, or if there are other reasons.

5.1 Reasons other than MatES

Was the subject of fractions easier to understand than the subject of geometry? Different teachers confirmed that both subjects have a similar level of difficulty the way they are taught in school.

Did the students have any knowledge about fractions? All students already had some basic knowledge on fractions, but also on geometry, because more or less the same efforts were spent on teaching these subjects over the previous 3 years.

Were the tests about fractions easier? The tests were similar, even identical to those made in the other classes the same, or a previous year. Furthermore, all tests (about geometry and about fractions) were corrected by two teachers.

5.2 Better understanding

Do the explanations from MatES help the students to better understand the explanations from classical sources (for example, books, notes on the blackboard or verbal explanations from the teacher)? Nine students stated that the explanations from MatES were very good and 3 students stated that MatES has a lot of knowledge. Nearly all students (21) stated that they found the right information using MatES, and 18 stated that they learned better with MatES. Here are some explanations:

- The semantic search engine helps the students to find a good answer quickly; in other words, they do not have to wait for the teacher to ask their question.
- The answer is very precise and short, unlike in a book, or long explanations from the teacher.
- The explanations are simple, and straightforward.
- The student can navigate through a clip, and stop at a more important part, or watch a clip several times.
- The information is presented in a more appealing form than in a book or on the blackboard. For example, several students remembered a certain information because they remembered a certain characteristic in a clip.
- The multimedia aspect activates more senses. The student hears, reads and sees the same information.
- Illustrations are used to explain a certain topic, which is more expressive than verbal communication [6].
- The video sequences show the presenter on the blackboard (or whiteboard). This is the students' common view in a classroom, and should create a kind of virtual classroom atmosphere; it is supposed to be serious work, and not a game.
- The motion on the screen keeps the students concentrated on what they do and draws their attention to what the presenter is explaining.
- The presenters were students. Some students accept more easily to be taught by colleagues than by adults.
- Students quickly acquired the specific vocabulary about fractions. If an unknown expression was used in a clip, then they could simply ask MatES to explain it.

5.3 Higher motivation

Every teacher knows how pleasant it is to teach in a class with motivated students. Industrious students generally produce good results, because they are willing to put more time and effort into learning. However, many students do not have an innate motivation to learn. Therefore, it is necessary to find means to convince them of the importance, and the need for this training.

There is the *intrinsic motivation* that is related to MatES, and the *extrinsic motivation* that is not related to MatES. The intrinsic motivation originates particularly in the desire of the students to understand the explanation of the presenter in the clip, to master this matter as well as the presenter, and to correct it (e.g. several students claimed that some subjects were not well presented, and that they could do better). It is also important to call forth the extrinsic motivation of the students during the experiment in order for every student to put all her/his effort in working correctly with MatES, and not to spend too much time watching and enjoying the clips. An extrinsic motivation was that the students who finished their exercises in school would have less homework.

The higher motivation can be traced back to MatES, because neither geometry, nor fractions are de facto motivating for most of the students. Maybe students have a small preference for geometry because they can use instruments, make drawings etc. whereas fractions are pure calculations. However, 20 students (90.9%) asserted that they enjoyed working with MatES. We even heard the statement: "With this [MatES], even mathematics is fun". Here are some reasons for their increased motivation:

- The use of new technologies is in general motivating for students.
- Everything that is different from the normal kind of teaching is, at least at the beginning, motivating for the students. For example, the lessons took place in a computer room, and they used a computer tool in mathematics, which is unusual.
- The explanations are presented in a more appealing form, i.e. short multimedia clips (see section 5.2).
- The student has the impression that (s)he is in control of the lesson. There is no teacher who dictates what to do next.

- The student is active in her/his learning process. Everyone is able to do something constantly, and to built her/his knowledge by his own action.

- In traditional courses, the stronger students mostly perform better, which is frustrating for others. However, this style of teaching easily enables each student to progress according to her/his own capacities, and none is embarrassed.

- The lessons can be perceived as a kind of adventure where the student plays the role of an explorer who discovers new information.

- The student understands better (section 5.2), and therefore has no reason to resign. In contrary, (s)he realizes that mathematics are finally not so difficult at all.

5.4 Greater Efforts

In our experiment, the students had to do a lot of extra work. These greater efforts could explain the better results. Firstly, as there were no "theoretical" lessons, the students spent most of the time doing exercises. Therefore, they had more time to find out about their weaknesses, to complete their knowledge, and to test it by solving the exercises. Secondly, they were aware that they had to learn and understand the theory in order to complete the exercises. Thus, it was in their own interest to acquire the necessary theory as soon as possible. Thirdly, the students knew that they had to finish their exercises at home. Hence, it was in their own interest to work in an efficient way in school in order to minimize their homework. Fourthly, weaker students had more homework because they progressed at a slower rhythm. This supplementary work and the required efforts to do it could have helped them to become better.

5.5 Different pedagogy

In a classical mathematics course, the student receives information from the teacher, and has to understand and to memorize it. The volume of information and the velocity at which the information arrives often overwhelm weak students [9]. Furthermore, if the student is not convinced of the importance of the information and the training, then the lesson is not effective.

MatES proposes a completely different pedagogical approach, which fosters autonomous and exploratory learning, and where the student becomes active in the learning process. With MatES, the student receives information only when (s)he asks for it. In this approach, the student directs her/his training; what (s)he wants to read, what is the rhythm of progression, how often (s)he wants to read the same information etc. She/He does not depend on the teacher or on the other students. Therefore, a weak student can progress in her/his appropriate rhythm. She/He can acquire knowledge about the same concepts as the rest of the class. If (s)he is a strong and ambitious student, then (s)he can progress faster and do more advanced exercises than required. She/He does not have to stay silent and inactive during the time the teacher explains the same information again to weaker students.

However, let us notice that this style of teaching does not foster learning by heart compared to *intelligent learning*. We observed that some weak students, which had acceptable results in mathematics in the past since they could study by heart, had worse results with MatES. To learn by heart is a strategy adopted by the students from secondary education which is not always effective.

5.6 Results

The data from the tests show that the students had better results when they used MatES. However, it cannot be proven if these improvements were really the direct consequence of the use of MatES. It is a fact that working with MatES was more motivating for the students, which in turn had a positive influence on the students learning and understanding. Therefore, MatES indirectly contributed to improving the students' school results.

An open question is how long students remain motivated with MatES, because today students quickly lose interest in what they do. Although students enjoyed using MatES for 5 weeks, the tool could become as boring as any ordinary schoolbook after another 5 weeks.

A regrettable fact is that students perceive computers in general and software in particular as a toy. The teacher's first task is to convince the students that the computer or the software is not a toy but a helpful tool. Games are funny at the beginning, but the student loses interest very quickly and asks for new things. However, if the student is convinced of the advantages of such a tool, then (s)he is likely to continue using it. For example, if students have to write a report, they immediately ask to use a word processor; thus they could write it without using a computer. A word processor is not perceived as a game, but as a useful tool.

We learned that students do only successfully and correctly use a computer tool, if they are convinced of its benefits, and if they know how to use it correctly. An example is a conversation between two students that we recorded during a lesson. Both students talked about the problem they had to solve an exercise. Then, one yelled spontaneously: "Let's ask MatES!". They knew that there was no obligation to use MatES, but they were aware that it could be of some help.

The success of our experiment is also partially due to the fact that the students were guided during the whole experiment, which is a requirement for a successful computer based training [5, 1, 7]. Therefore, MatES did not reduce the volume of work for the teacher. It is clear that students need more guidance and ask more questions if they become active in their learning process. Furthermore, in traditional learning environments, teachers are primarily responsible for the organization, delivery and assessment of content acquisition by students in their courses. This changes as soon as teachers use e-Learning technologies. They receive additional roles like technology specialist or administrative advisor.

The quality of the semantic search engine is a crucial factor of the success of MatES. We know that students generally dislike getting multiple results; they do not even consider them all [1]. Students have clear expectations about the requested search result. Even if MatES yielded 5 results, which was quite unusual because normally the number of results was smaller than 3, some students complained about this "high" number of clips ("Do I need to watch all of them?").

6. DEVELOPMENT DETAILS

Development of this type of application requires creation of a knowledge base (for example, fractions in mathematics), or use of an existing knowledge base (for example, .ppt-presentations, .pdf-files). These documents must be described with enough metadata (i.e., OWL, the Web Ontology Language) to make the search engine understand the semantics of the content. With a knowledge base in place, a system's dictionary must then be created or adapted and organized in a hierarchical way (similar to *WordNet*). Finally, after some small configurations of the search engine, the system is ready to be used.

The most painful task is the creation and annotation of the knowledge base. Once the system configured, there no necessity for special personnel to administer or maintain the system (except if adding new content to the knowledge base or adding new words into the dictionary).

The system exists as standalone application and as online application. As for the first one, the knowledge base, the search engine and the user interface can (all three of them) be located on different machines. In our experiment and for performance reasons, all three were located on the student's local machine. We managed to store the whole knowledge base with the application software on one single DVD. No installation or configuration is required; the student can immediately run the application from the DVD. As for the online version, it uses a streaming server to transmit the clips to the user's browser.

7. CONCLUSIONS

In this paper we showed that e-Learning can improve school results. With our e-librarian service the student is active in his learning process, and plays the role of an explorer, would result in higher motivation, i.e. the students are willing to put more effort into learning mathematics. Furthermore, the simple multimedia presentations helped the students to better understand a certain subject without the help of the teacher. This is particularly helpful for shy and weak students, as well as those who speak a foreign language and who are slow in articulating themselves. Basic knowledge from previous school years, can be refreshed in a autonomous way.

Our e-librarian service can be used in different situations. In our experiment, we used it to introduce a new subject in an autonomous and explorative way. But it can also be used in a *blended learning* approach, where the teacher decides in which lesson it is most appropriated to use it. It can also be used for *distance learning*, where a student (or a professional) can learn at home. Another interesting aspect is for *collaborative learning*. Students can work in a group and collect information, which they share and discuss later.

For future work, we could imagine that in a *virtual reality learning* approach, MatES could supply various exercises, explain the students' mistakes, and suggest corrections or clips to watch.

Some disadvantages are that students have no possibility to preserve the learned information in written form. There should be a possibility to print snapshots, or to copy the textual content of a clip into a word processor. A general problem of e-Learning is the availability of computers. In practice, not every teacher has access to a computer room for his lessons. MatES is most efficient if each student can use a computer individually.

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