Why Learning Analytics for Primary Education Matters!

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***Abstract*—The ubiquitous availability of applications enables us to offer students opportunities to test and train competences in almost every situation. At Graz University of Technolgy two apps for testing competences in multiplication are developed. They estimate the competence level of every user and adapt to their individual development in this domain. They collect a lot of data during a longer period, which could be used on further research. In the foreground they give feedback in a compact and clearly arranged way to the single student and the teachers of classes. But furthermore the analysis of the data during a longer term showed us, that the process of testing and giving feedback has also an positive effect on learning. We emphasize that this quality in supporting the students could not be achieved by human teachers. Information Technology and Learning Analytics gives them a wider radius to perceive specific behavior and establishes their capacity for storing and processing all the relevant data.**

***Index Terms*— Electronic learning, intelligent tutor, multiplication tables, Learning Analytics**

I. Introduction

Learning analytics is an increasing research topic in the field of Technology Enhanced Learning (TEL) and became international popular since the Horizon Report 2012 described it as a forthcoming trend [1]. Phil Long and George Siemens stated [2] that "the most dramatic factor shaping the future of higher education is something that we can't actually touch or see: big data and analytics". But even before the first Personal Computer (PC) had been introduced to classrooms, educational researchers attempted to realize an Intelligent Tutoring System (ITS) to assist children in their daily learning processes. This first attempts and all the further ongoing work is nowadays described as Educational Data Mining (EDM) which has a long research tradition [3]. Romero and Ventura [3] pointed out that Learning Analytics (LA) is a part of EDM whether this is not clear in the current debate. Nevertheless the most important research question in respect to LA seems to be: What exactly should be measured to get a deeper understanding of how learning takes place [4]?

LA depends on the growing possibilities to generate data about each single learner, to combine these date with learning activities in accordance with didactical instructions. With other words LA strongly relates to the context, to the so-called learning behavior. Lotze & Tatzal [5] mentioned that LA helps us to understand learning more deeply.

George Siemens is looking for additional information through big learning data to predict learning success [6]. He also pointed out that not the models of analyses are important, but the whole process. LA is also related to interventions by teachers, the adaption of learning instructions, or the predication of learning success as well as social connections. LA can be differentiated from the primarily EDM due to the fact that LA is more than just interpreting data and related automatic processes. It is the assistance of instructors, teachers, and lecturers with appropriate data to enhance the learning behaviors of each single learner – individualized and personalized.

Schön et al. [7] defined LA as interpretation of big learning data to enhance the individual learning process.

II. Learning Math in Primary Schools

A. General Overview

In this publication we want to show that research work concerning LA is interesting and also already necessary for education in primary schools. Personal computers are available in most of our classrooms. Now we can recognize that more and more students have smartphones and pads/tablets to use internet based applications [8]. It seems obvious that the ubiquitous integration of mobile devices with stable Internet connection is just a matter of time. Therefore Graz University of Technology (TU Graz) began to take care about related research in the field of mobile learning and Learning Analytics especially for the youngest school children. The very first approach is about learning math due to the fact that the number of problems is limited.

The research question we address in this work is how can LA be helpful for learning math in primary education? In our case the implementation concentrated on learning the multiplication table and multi-digit multiplication.

B. Theoretical Background

Nowadays lot of effort is put on the development of software to improve practicing the multiplication tables for school children. As a result of our concept phase in the beginning of the project teachers characterize "learning the multiplication table" is an enduring core problem of the first school years. Furthermore, wrong calculations of single multiplications are

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often the cause to further problems in the next step of basic mathematics, for example, multi-digit multiplication.

After a first interview about the quantitative extent of the problem teachers were only able to give approximate and exemplary information about the skills of their pupils. One of the most announced phrases were: "There is one, who is very good .... and another ....".

Learning the multiplication table seems to be a very simple problem in the beginning, because there are only 10 times 10 problems, which children have to memorize. The competence to produce results is finally not a general competence that delivers results with a random error. Due to the fact that the result of each problem has to be known, the training situation differs arbitrarily from those that are well researched using intelligent tutoring systems (ITS) and predictions of a certain level of knowledge. Furthermore, there is also a lack of knowledge about the way individuals learn the multiplication table best. Of course, there are different methods to solve the problem for each of us. Sometimes fingers play a role or similar other tricks. But the general recipe for learning the tables is still "drill & practice".

It can be summarized that it is of high importance that every single of the hundred multiplications should be done by each learner reliable. From this perspective, it becomes an information-processing task for the teacher to attend them adequately. The teacher for example has to decide, whether the child meets the competence to begin with the multi-digit multiplication or the child may work as a reliable tutor for other students.

C. Pedagogical Approach

Multiplication tables seem to be mainly a problem of drill & practice. Considering current didactical knowledge about learning math it can be pointed out, that some of the basic knowledge about mathematics is acquired even before children start school. As one reason there are cultural differences, some obviously based on language implications [9]. Each child needs a general linguistic competence before starting to operate with numbers. Some publications point out that mathematic is even the first non-native language [10]. Understanding the expression "multiply" is implicit not only a mathematical problem but also a linguistic one. Many children who carry out the algorithms correctly do not really understand reasons for crucial aspects of the procedure [10].

From the perspective of special education it is well-researched that learning as well as teaching math only by memorizing results is problematic and leads to disorders and blockades on the learner side. According to current neurological oriented research results, but also based on a very old educational tradition, teaching should use tactile, optical and acoustic processing methods in every single case – even more intensive when we observe anomaly from the mainstream. It is important to allow math to be taught in a multisensory way to children with special educational needs. Kendall [11] offers some practical suggestions how to achieve this. But the daily experiences are dominated by pure "row learning" of the multiplication table [12].

Bearing in mind that the competence "perfect handling the multiplication table" differs arbitrarily from required learning time and learning effort; it seems obviously that the simple problems "learning the multiplication table" is not as trivial as it seems to be on the first glance. The goal of our research work was to develop a web based intelligent system for testing and perhaps training the multiplication table that is accessible from any web browser to assist learners as well as teachers.

Furthermore, it should provide teachers a quick overview about the current learning process of their pupils. Our research group, consisting of educators, e-learning experts, educational scientists, and IT-developers specified the requirements beforehand as follows:

- The system should estimate the competence grade of the learner
- The system should record and store data of all done exercises, test results and the current competence grade of the learner in order to prepare the next sessions in an adequate way. The goal is to generate a complete table to inform learners as well as teachers about their competence in every single task, actually about every single multiplication fact
- The system should provide appropriate tasks according to the competence grade of the learner.
- The system should ensure that already well-done exercises are repeated and practiced continuously. After succeeding a problem the probability for a repeated display should decrease in two levels as already suggested by the well-known "Leitner system".
- In general the system should be motivating and show that learning can be fun. Nevertheless the tasks should tend to be challenging.
- Thereby it should unburden the teachers from any administrative tasks.
- From a technical perspective the system should run on the web and on many different clients. Therefore the script language PHP and a MYSQL database were chosen. Furthermore native applications for iOS devices (iPhone, iPad) and Android were developed.

III. Some Simple Examples

A. General Remarks

In respect to LA, web-based applications should be programmed in order to enhance the individual learning behavior of each single child. From a technical perspective this program (trainer) should be available from anywhere with any device. Therefore a web-based solution was chosen with a so-called API, which allows mobile devices to have access too. Furthermore, each single calculation is stored in the database for an individual evaluation of each learner.

B. Multiplication Table

First of all it is important to mention, that the web-based application works with an intelligent algorithm for choosing the next question; due to the fact that a too easy question bores learners and a too difficult one demotivates them to go on.

Therefore different categories or areas were introduced. A random number between 0 and 1 is chosen to decide which category is activated to generate the next multiplication problem. Three different possible cases are defined:

- Case 1: If the random number (x) is smaller or equal 0.05 than a well-known question marked with 2 is chosen.
- Case 2: The random number is 0.05 > x >= 0.15 than a known question marked with 1 is chosen.
- Case 3: The random number is x > 0.15 than a (unknown) question out of the extended and actual learning area is chosen.

The extended area follows the idea that not only items of the learning area are chosen, but also items exceeding the level of competence (0.15).
Finally data of already done calculations are used for adjusting the competence level from the estimation at the beginning.

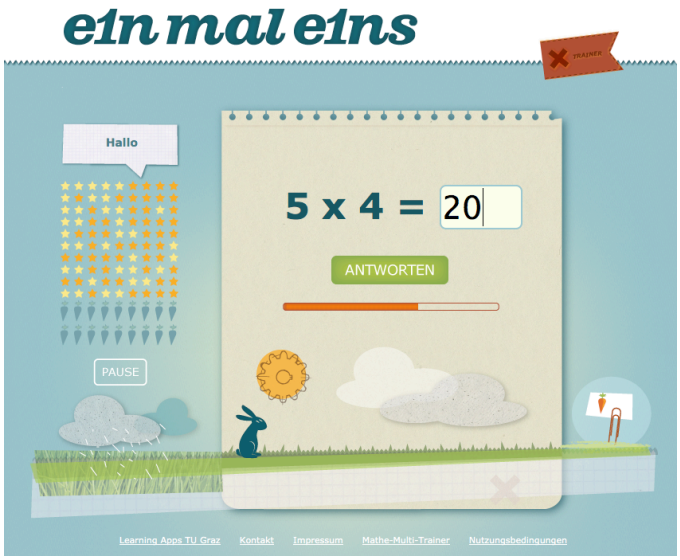

Fig. 1 Screenshot of the multiplication trainer (http://mathe.tugraz.at)

Fig. 1 shows the main screen of the trainer. A problem is presented which has to be solved within a defined time frame. On the left side each already correctly solved problem is shown (yellow = well known; orange = known).

Multi-digit Multiplication [14]

In a very similar way a web-based application has been built that should assist learning multi-digit multiplication:

1. an overall learning algorithm that sets the difficulty for multiplications adaptively and independently for each user,
2. the generation of multiplications of a specific category (of difficulty),
3. the analysis/evaluation of the results of the generated and displayed multiplications (= user inputs), categorization of the detailed results (multiplication, addition alignment).

In respect to EDM the learning application has to adapt to the current user's expertise in multi-digit multiplication knowledge. To do so, we defined a hierarchy of multiplication problems that differ in difficulty. Another main objective of the algorithm for generation multiplication problems is to offer a large variety of examples at the same time. On the basis of [13] we distinguished eight different problem groups of multi-digit multiplication. The overall domain of definition includes multiplicands (left factor) with 2 to 4 digits and multipliers (right factor) starting from 1 up to 3 digits in size. Beside these categories of difficulty, the concept of written addition and multiplication includes another dimension: the carry. In our application simple multiplications without carry and multiplications including a carry are separated.

Fig. 2 Main screen of the multi-digit trainer (http://mathe.tugraz.at)

Fig 2 shows a screenshot of the final trainer. A problem is presented and each learner has to fill in the given fields.

IV. Discussion

In order to analyze the data in respect to LA a user-management was introduced that not only allows children and teacher to register, but also to define schools and classes as well. This means that an instructor can see the results of a single child, the class or his/her school.

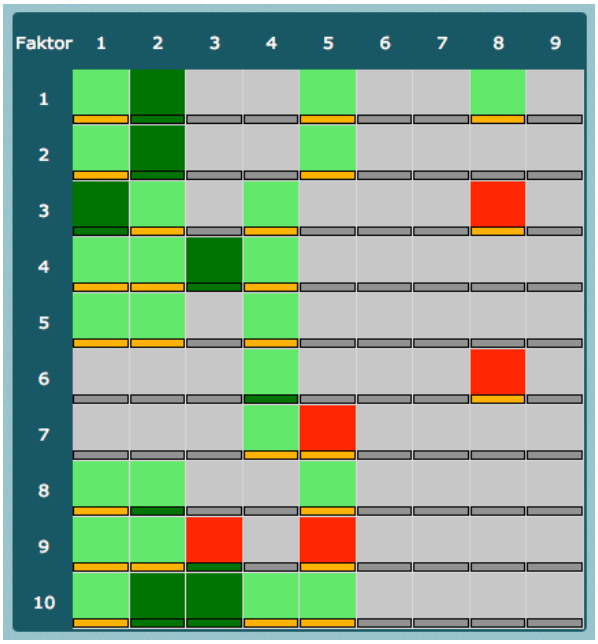

Fig. 3 Analyses of one single child (http://mathe.tugraz.at)

Due to the fact that each single calculation is stored in the database it is easy imaginable that the interpretation of the data of just one single child needs arbitrarily time. So there is an urgent need for a first fast overview, that enables teachers to decide quickly, whether they have to intervene or not. Therefore a simple visualization was chosen. A table of all

calculations is visualized overlaid with four colors (see Fig 3). Dark green marks "well-known" calculations, light green marks "known", red that is unknown and grey that the calculation was not done yet. With the help of this traffic light scheme teachers can see in seconds how well each child performs and which specific action of the teacher may be needed. With other words, for the first time it is possible to determine exactly for each child it´s problems with the multiplication tables.

During a longer period we can state for most of the cases an increase of the student´s competences. For some students these apps are not a real problem. They just are getting perfect by correcting some problems with single multiplications. For many others we observed a development – learning.

Fig. 4 shows for example the increasing learning rate of one single child. In the very first beginning only about the first 20% of the multiplication table are well-known. Following a longer time period with no real increasing success. Finally after about 300-presented examples the number of right solutions increased arbitrarily. So it can be assumed that a learning process occurred perhaps because a teacher gives important instructions to help this child.

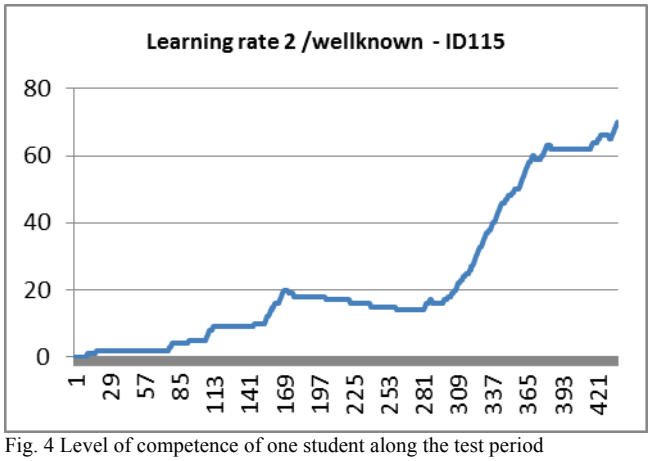

Fig. 4 Level of competence of one student along the test period

V. Conclusion

LA brings new insights into the classroom. For the first time we are able to observe in an economical way single steps and solutions of every child during a longer period. We started with the expectance to improve the diagnostic of some problems with the multiplication table and multi-digit multiplications. Our results show: automated precise testing and feedback can be seen as an individual assistance and an effort to an effective learning process.

It is remarkable that normal teachers don´t have enough capacity in perception and mind to realize a similar competence in classrooms. This is so to say a unique feature of this application for LA.

Our future works will not only focus on math, but also on first attempts in language education. For example, currently a trainer is implemented to measure the reading competences of school children. We see that behind the holistic perception of a child´s reading competence there are some simple partial competences which could be observed, measured and perhaps trained without appreciable investments – and without additional stresses and strains for the teachers.

Finally we like to summarize that Learning Analytics is an important step to give the learners precise feedback and shows how teaching of tomorrow can support and promote each individual learner exactly at the state needed.

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