Computer-assisted Learning in Primary School Mathematics Using ViLLE Education Tool

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ABSTRACT

This study is a research conducted in Finnish primary school for 18 third graders to find out how computer-assisted learning affects the learning results of the pupils. Besides learning results, this study also discusses the pupils' opinions on computer-assisted learning and the used education environment. The exercises used in this research were developed for this study and are based on learning theories and social aspect of learning discussed in this paper. The results from these research problems are very encouraging and show that the computer-assisted learning has great potential.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education – *Compute-assisted instruction, Collaborative learning.*

General Terms

Design, Experimentation, Human Factors

Keywords

Computer-assisted learning, ICT in schools, Collaborative learning

1 INTRODUCTION

There has been a lot of talk about how to bring the benefits of computer-assisted learning into classrooms [32]. The internet is full of different applications which have been developed for educational purposes. Often these applications fall short on customization, and often they don't gather information about user interaction and results. These applications are also designed to be used by only one user at a time, in other words the collaborative nature of learning is lost. ViLLE collaborative education tool rises against this problem. This article evaluates computer-assisted learning and how the learning results are affected by usage of computer-assisted learning. The article focuses on third grade mathematics but the same principles are valid for younger and older pupils and students.

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This study combines knowledge from both education sciences and computer sciences. Combination of the strong knowledge from both sides is used to develop applications, which are good from both the educational and the information technological perspectives. Some of the features discussed in this study, including automated assessment and immediate feedback, are already built into ViLLE [12], [13], [14], [30]. These features are utilized in the exercises according to education sciences. The goal of this paper is to evaluate learning results of specially targeted math exercises built into ViLLE education tool.

The aim of this study is to follow the usage of ViLLE collaborative educational tool in teaching of mathematics, as well as to find out what is the effect of collaborative learning, visualization and immediate feedback on the third graders' decimal calculation learning results. Besides learning results, this study also tries to determine the research subjects' opinion on computer-assisted learning.

Collaborative learning means building a common knowledge base on a certain subject in social interaction between the participants. Tasks are not divided among participants but instead they are handled collectively. Collaborative learning triggers cognitive processes in individuals, and these processes are essential for learning to take place. Although the processes occur in individuals, they are known to be triggered in social interaction [7]. When explaining, a pupil must analyze and structure one's knowledge in order to be understood. When evaluating information, pupils need to compare new information to the knowledge they already have. Different opinions are valuable for the development of problem solving skills, and they generate cognitive conflicts that need to be solved [10].

Metacognition and cognitive load are tightly involved in collaborative learning. Cognitive processes take place in working memory. The load of working memory is called cognitive load [26],[29]. Working collaboratively makes it possible to share the cognitive load and allows individuals to concentrate on higher cognitive functions. Metacognition on the other hand means knowledge of one's own cognitive processes. This knowledge forms the foundation for self-regulation and for different learning strategies [21].

2 PREVIOUS WORK

This chapter presents information about computer-assisted learning, interaction types regarding computer-assisted learning, and general learning theories. These theories form the basis for understanding better software development for education. There is also a brief discussion about teaching math and a short description of ViLLE collaborative education tool.

2.1 Computer-Assisted Learning

Computer-assisted learning (CAL) is a widely studied subject. It has been shown that CAL can improve the learning results and knowledge of students, when applied correctly [[15], [17], [33]. Kulik & Kulik and Vogel et al. have done a comprehensive meta-analysis on computer-assisted learning and shown its impact on learning results.

Kuo-En, Yao-Ting and Shiu-Feng have done a study on computer-assisted math learning on fifth graders in Taipei. 132 pupils took part in the research. Pupils participating in the computer-assisted learning succeeded better in problem solving exercises than the control group. The key findings of the research were that instructions and feedback reduced pupils' cognitive load and frustration, and gradual solving supported pupils' problem solving skills [18].

When computer-assisted learning is combined with learning perspective's social aspect and with collaborative learning, a concept called computer supported collaborative learning (CSCL) is achieved [24], [31]. In CSCL, software participates in interaction, by giving feedback to it is users or by acting as a supportive environment for discussion and learning. In both cases, software enforces collaborative aspects of learning [31]. It has been shown that this collaborative nature of learning will improve learning results and motivation among students [11], [15].

3 TYPES OF INTERACTION

Moore [28] divides interaction into learner – content, learner – instructor and learner – learner interactions. Bouhnik & Marcus [3] have suggested one more type, learner – system, into Moore's theory. All these interactions are present in computer-assisted learning. Recognizing this division is important when designing an effective computer-assisted learning environment.

In learner – content interaction pupils construct new knowledge based on previously learned facts and new facts provided by educational material (content). The learner – content interaction can be described as a didactic dialect between pupils and the educational material. The material provided to pupils should be divided into meaningful entities and it needs to be easily accessible. Otherwise it takes a lot of effort to find the relevant information, and that distracts pupils from learning [3].

Learner–instructor interaction is a versatile relation, and in primary school environment it includes besides verbal and written feedback, also non-verbal interaction, such as physical presence and eye contact. If learner–instructor interaction is solely computer-mediated, a big part of the interaction is missing. The lacking aspects expose the interaction to misunderstandings. It is vital to this kind of interaction that the instructor maintains sufficient level of interaction to engage the learner into the learning process [3].

Learner–learner interaction is the backbone of collaborative learning. This interaction is all about the students asking questions, sharing ideas and disagreeing with each other [3]. In other words, this interaction reflects one's own knowledge and it develops the learner's metacognition.

Learner–system interaction provides the framework and tools for learning. This separates learner–system interaction from learner–content interaction, which is all about education material. The system should be as unobtrusive and as invisible as possible to the learner, so it won't stand in the way of learning. The system defines the means to communicate and share knowledge between learners [3]. Laakso points out that two important aspects of learner–system interactions are automated assessment and immediate feedback [20], [21]. Automated assessment bonds learner with the system and learning, keeping the learning process uninterrupted. The system acts also as an expert asking the right questions to helping the novice (learner) to learn [16].

3.1 Learning Perspectives

Learning is a complicated process, which happens via cognitive mechanisms, and is still widely unknown. There are multiple models and theories formed to describe these processes. Since none of these theories can explain learning on their own, it's reasonable to combine them when observing learning. Three of the commonly used learning perspectives, behaviorism, cognitivism and constructivism, will be presented in this study. The basic understanding of learning is important when designing educational applications. Without this knowledge, a lot of important aspects of learning and supporting functions might be forgotten.

In behavioristic learning theory pupils are encouraged to certain type of behavior. The wanted behavior is awarded and reinforced. Behaviorism is based on stimulus and reaction, and knowledge is seen as a baton, which is passed on from the teacher to pupils. Behaviorists think that anything can be taught, if only a correct stimulus is found. Behavioristic learning theory is outdated in a larger scale, but it can be applied in smaller scale, teaching simple mechanic functions [2], [32].

Cognitive learning theory is based on an idea that learning is a cognitive process, which consists of remembering, thinking and making decisions. Learning happens, when new knowledge is compounded to the knowledge already learned. New knowledge can collide with old information, which creates a cognitive conflict. The conflict must be resolved before learning can take place [32], [1]. In other words pupils have to construct knowledge on their own and it can't be given by the teacher in comparison to behaviorism. Social interaction activates cognitive processes [7].

Constructivism is a modern theory of learning. It divides into many disciplines and the definition of constructivism varies [34]. Constructivistic learning theory adds the concept of environment to cognitivism, and the pupil is seen as an active constructor of knowledge. Teacher's role is to provide a stimulating environment, where the pupil constructs his/her knowledge through cognitive processes based on previously learned knowledge and experiences. Teacher needs to feed the pupil's interest and desire to learn. The knowledge is constructed in social interaction with the teacher [2], [32].

These learning perspectives can be seen as parts of Piaget's sosio-cognitive theory and Vygotsky's sociocultural theory [10]. In the former, knowledge is built through sosio-cognitive conflicts, which occur when different opinions or points of view are suggested. These conflicts need to be resolved in order for learning to take place [1]. In sosio-cultural theory, knowledge is seen as a product of social interactions in a certain historical and cultural environment. Hence it is necessary to analyze the tools and norms the society provides for learning and interaction [1]. Vygotsky extends Piaget's ideas of social interaction to concern space, time and tools.

When discussing about the work of Vygotsky, it's also meaningful to bring up his theory of zone of proximal development and scaffolding [6]. According to Vygotsky's theory, learning happens in the zone of proximal development, where an expert supports a novice and helps the novice to gain greater knowledge step-by-step. The novice is able to function at the zone of proximal development with the help of an expert but not independently. The goal of teaching is to widen this zone [10]. The term scaffolding is used to describe the expert's role in the theory of zone of proximal development.

3.2 Multimedia Learning

Visual and verbal forms of presentation are both independently processed in the brain. By combining these two ways as a meaningful combination to present knowledge, it is possible to support the learning process and improve the understanding of concepts. The research results state that pictures alone are not efficient to advance learning results, and that they need suitable verbal explanation to achieve efficiency [25]. This concept is taken into account when visualizing the math exercises. Decimals and fractions are not only shown in written form, but they are also visualized as pictures (see figures 1–6).

It is important to note that a multimedia presentation should help students to concentrate on the important parts of the material and not interrupt the learning process [12], [27] The idea of multimedia learning is to reduce the cognitive load on students and freeing students' learning capacity, rather than just act as a motivator [27].

3.3 Teaching Mathematics

Mathematical skills are cumulative. In other words, previous knowledge is necessary when learning new skills [8]. Counting with decimals requires knowledge of 10-base system. Hiebert and Wearne have studied the 10-base concepts development and conclude that the concept of 10-base system needs to be understood before it can be utilized in exercises [9].

Exercises used in this study are designed to support the concept of 10-base system through visualization and verbal notations to 10-base system. This is achieved by marking the place values to the visualizations (see figures 4 & 5 for reference). According to Mayer's and Chandler's research [27], the verbal form of presentation combined with visual presentation enhances learning.

3.4 ViLLE

ViLLE is a collaborative education platform developed at the University of Turku. It enables teachers to create virtual assignments and keep track of students' or pupils' progress and scores via automated assessment. Although ViLLE has a vast set of predefined exercises, it also allows teachers to customize any exercise to meet their needs 0. This is also one of the key factors, which separates ViLLE from other existing applications. The learning results using ViLLE tool have been studied in the field of program visualization and there are a lot of encouraging results on the effectiveness of ViLLE. Programming and mathematics have a lot of similarities, and the exercises developed for this study follow the same principles of visualization and immediate feedback that previously studied programming exercises use [12], [13], [14], [30].

4 METHODS

This study was conducted in a Finnish school on third graders of age nine. The chosen class had some prior experience of computer-assisted learning, and the school had all the equipment necessary to carry out this research. All of the pupils ($N = 18$) in the research class participated in the research. Main goal of this research was to follow the usage of ViLLE collaborative educational tool in teaching of mathematics, as well as the effects of that usage on individual learning results. The third and final goal of this article is to determine the research subjects' opinions on computer-assisted learning.

The mathematical theme of the study was decided in collaboration with the teacher of the research class. The exercises are a revision of previously learned addition and subtraction of decimals, and transformation of decimals and fractions. Verbal exercises in this theme were also included in the study. Research exercises are partly based on the text book used by the research class, Matikka 3 (spring part) (Rinne, S., Sintonen, A-M. & Uus-Leponiemi, T. 1.–3. edition. 2011).

The study method used in this research is called intervention research, although it combines characteristics of experimental research, action research and intervention research. Intervention describes best the research configuration in this study. The conducted study corresponds to the exposition of Lehtinen, Jaakkola, Veermans and Hakkarainen on the experimental research with quasi-experimental research setup [23]. However this study did not include a control group. Some similarities can also be found with action research, which aims to produce new information and use this information to develop current practices. However, this study does not share the iterative and self-analyzing feature of action research [4], [19][23].

4.1 Research Method

Three types of mathematical exercises were developed into ViLLE to study learning results of third graders in the field of decimal calculus. Exercises were developed using practices discussed in this paper to maximize learning and meaningfulness. Visualization was used to concretize figures and calculations. Goals of the visualization were to illustrate and confirm the students' number sense. After user input, every exercise provides the user immediate feedback about the given answer, its correctness and the correct answer in its different forms. Features of visual feedback and different exercise types are discussed in greater depth in chapter 4.1.1. Immediate feedback is a very basic feature of behaviorism [5], however the immediate feedback is designed to support the constructivistic aspect of learning via multiple ways of visualization.

The study consists of two lessons. In the first lesson research subjects were familiarized with ViLLE, and they conducted a pretest. Exercises in the pretest were based on the exercises designed for ViLLE. During the second lesson research class made ViLLE exercises in pairs. This was followed by a posttest. Learning results of the research subjects were evaluated with these two tests.

4.1.1 Exercise Types and Design Principles

Three types of exercises revising the third grade decimal calculus skills were designed and developed for the intervention. The first exercise is for addition and subtraction of decimals. Second exercise is about transformation of decimals to and from fractions. The third exercise is also for addition and subtraction with decimals, but it extends the first exercise so that the figures used in the calculation must be read from a bar chart. This exercise is also verbal, which means that the research subjects need to decide the correct operation from the context. In every exercise type the figures are generated randomly when the exercise is loaded. This means that the same exercise can be done multiple times with different calculations.

The exercises are designed to make math visible through visualizations of the calculations. The given visualization is designed to highlight important mathematical concepts and support the cognition of the pupils. Visualization is utilized based on Myer's work and its purpose is to support learning according to learning theories [25], [27]. Immediate feedback provides information about the success of the user, but it also provides additional information on the correct answer. Immediate feedback shows the user's answer and the correct answer in alternate forms. In this case, the forms are decimal, fraction and pie chart forms. This is designed to develop the user’s metacognition, in other words, to make their thinking visible [21].

Calculating with decimals. When calculating with decimals, figures are illustrated with green rectangles. Full set of ten rectangles illustrates a whole number, and rectangle set containing less than ten rectangles illustrates the tenths. Place value is written on top of the figures to familiarize pupils with these terms, and clarify the meaning of place values and magnitude of the numbers. For the pupils, this representation concretizes the written and the visualized forms of the number. Visualized form represents the amount related to the number. This concretes the number sense of the pupils. Rectangles turn to red when they are clicked with a mouse. This enables pupils to visualize the given calculation. For example when solving the calculation in figure 1, pupil can click twelve rectangles from the number 2.1 and calculate remaining green rectangles to get the correct answer.

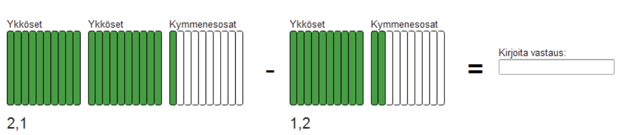

Figure 1. Subtraction with decimals

Like in the decimal calculation exercise
, the degree of difficulty can be modified by choosing the minimum and maximum value (0–6) of the numbers used to generate the calculation in the exercise. The degree of difficulty can be modified also by choosing only addition or subtraction or both of them as possible operations.

Transformation. In the transformation of numbers, decimals are transformed into fractions and fractions into decimals. Decimals are visualized with rectangles, identical to the visualization of decimal arithmetic (figure 2).

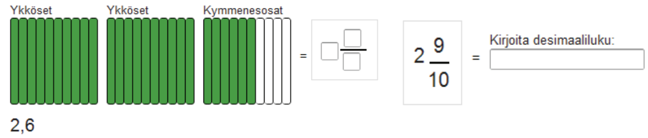

Figure 2. Transforming decimals into fractions and fractions into decimals.

The degree of difficulty can be modified by choosing the minimum and maximum value (0–6) of the numbers used to generate the calculation in the exercise. Teacher can also limit the direction of transformations included in the assignment in a way he/she sees fit.

Verbal exercises and reading from a bar chart. The verbal exercises are formed from an assignment, a bar chart and a question (see figure 3). Assignment is a short portrayal written by a teacher, explaining the exercise and giving a framework for it. Pupils need to be able to interpret the bar chart and pick up values needed for the given assignment. To assist the interpretation, there is a line for every tenth, and at the end of every line there is a written the value of the line. Pupils need to decide themselves whether the asked question is an addition or subtraction assignment.

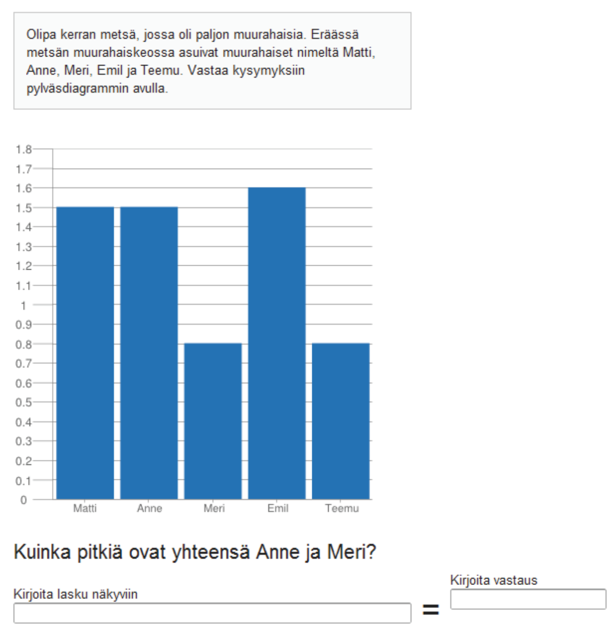

Figure 3. A verbal exercise. “How long are Anne and Meri altogether?”

This exercise is no exception from the previous ones. The degree of difficulty can be modified by choosing the bounds for random numbers and opt which operations to ask.

Immediate feedback

Every exercise mentioned before utilizes similar immediate feedback after user input. When answered correctly, the input field is replaced with a green answer box, which contains the correct answer as a decimal, a fraction and a pie diagram (figure 4). Answer is always shown with accuracy of one tenth.

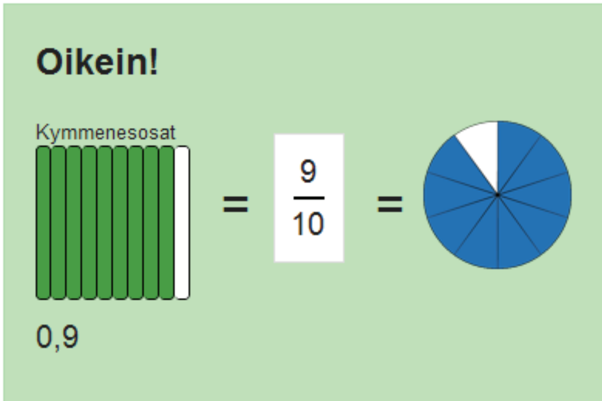

Figure 4. Immediate feedback when answered correctly.

If the user's answer is incorrect, the input field is replaced with red answer box (figure 5). The box consists of the user answer and the correct answer in all of the three forms, similarly to the correct answer case. The incorrect answer's box is red in contrast to green for correct answer, to ease the interpretation of correctness. The heading of the feedback is designed to be encouraging. If the answer is correct the heading is simply “Correct!”, but when answered incorrectly, the heading states freely translated “A little more focus”.

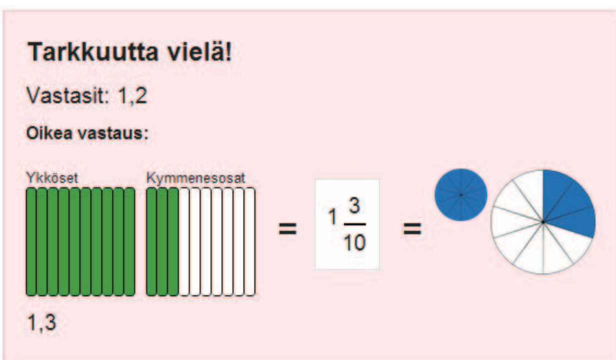

Figure 5. Immediate feedback when answered incorrectly.

In addition to immediate answer feedback, verbal exercises have an extra feedback in the bar chart (figure 6): Asked bars are colored in red to visualize the correct values for pupils. (Compare figures 3 and 6).

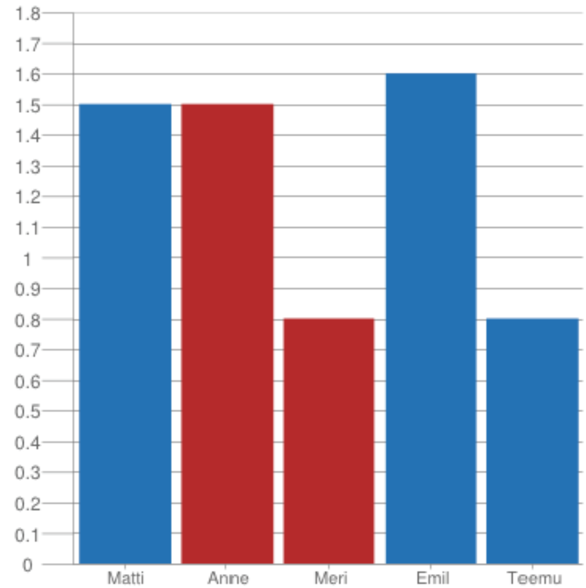

Figure 6. Immediate feedback in the bar chart.

4.1.2 Exercise Types Used in the Study

The exercise types introduced in chapter 3.1.1 were used as a basis for the assignments, and assignment rounds were formed out of exercises (table 2). Five rounds were prepared for the research subjects in order to get them familiar with ViLLE system and computer-assisted problem solving.

4.1.3 The Test

The skill level vas measured before intervention with a pretest. After the intervention, the learning results were evaluated with a posttest, which was identical to the previously used pretest, so that the results are comparable between pre- and posttests. However in the posttest was included two questions freely translated “How well did you manage to solve the given exercises?” (poorly – very well) and “What was it like to do these exercises?” (boring – fun). Questions were answered by marking the corresponding spot on a line segment to match his/her liking. These questions were designed to find out how the research subjects feel about computer-assisted learning and these specific exercises. Both test were done manually with pen and paper to avoid technical issues during testing. There also weren't enough computers to do the tests individually.

The tests were constructed from screenshots of exercises in ViLLE, so they match the exercises research subjects solved during the intervention. A special round was made in ViLLE for the tests. All the exercises included in the tests are listed in table 1.

Table 1. Exercises used to form the pre- and posttest.

Exercises used in both pre- and posttests.
- Addition of decimals [0, 1] 3 pcs. - Transformation between decimals and fractions, both ways [0, 2] 4 pcs. - Addition and subtraction of decimals [0, 3] 6 pcs. - Verbal exercise, addition and subtraction [0, 2] 2 pcs.

The first exercise is designed to be easy, so that the research subjects find a flow to make the whole test. The exercise consists of addition of decimals from zero to one. From every correct answer, the research subject scores one point. Second exercise is a transformation exercise with two transformations from decimals to fractions and two transformations from fractions to decimals. From every correct answer, the research subject scores one point. There are six mixed additions and subtractions of decimals in the third exercise. In the test there were four subtractions and two additions. Every correct answer increased the research subjects' points by one. The fourth exercise is a verbal exercise with two problems, one addition exercise and one subtraction exercise.

Table 2: Exercises used in the research

Round	Exercises
1. Practice	- Addition of decimals [0,1] 5 pcs. - Subtraction of decimals [0,1] 5 pcs. - Transformation from decimals to fractions [0,1] 5 pcs. - Transformation from fractions to decimals [0,1] 5 pcs. - Verbal exercise, addition [0, 2] 1 pcs.
2. Easy exercises	- Transformation from decimals to fractions [0,1] 5 pcs. - Transformation from fractions to decimals [0,1] 5 pcs. - Addition of decimals [0,1] 5 pcs. - Subtraction of decimals [0,1] 5 pcs.
3. Moderate exercises	- Transformation from decimals to fractions and vice versa [0,2] 5 pcs. - Addition of decimals [0,2] 5 pcs. - Subtraction of decimals [0,2] 5 pcs. - Verbal exercise, addition [0, 2] 2 pcs - Verbal exercise, subtraction [0, 2] 2 pcs.
4. Difficult exercises	- Transformation from decimals to fractions and vice versa [0, 4] 5 pcs. - Addition and subtraction of decimals [0, 3] 5 pcs. - Verbal exercise, addition and subtraction [0, 2] 4 pcs.
5. Extra exercises	- Transformation from decimals to fractions and vice versa [0, 4] 5 pcs. - Addition of decimals [0,2] 5 pcs. - Subtraction of decimals [0,2] 5 pcs. - Verbal exercise addition and subtraction [0, 2] 4 pcs.

4.2 The Intervention

First lesson of the study was held in the ICT classroom of the school on Thursday 10th of May 2012 at 12.30–13.15. One of the authors was responsible for the planning and keeping the lesson. Computers in the class were logged in to ViLLE before the lesson. The teacher of the research class brought the pupils into the classroom and divided them into pairs, one pair per workstation. Working in pairs makes it possible to solve problems in collaboration with the partner. The pupils were informed about participating in a research, which includes a pretest, one lesson and a posttest. The pupils were taught to use ViLLE tool via a video projector and they followed the researcher's step-by-step guidance. Learning process was fast and after a few minutes the pupils started to work on their own with practice round's exercises. The practice round familiarized students with the exercise types asked in the pretest. Pupils had about ten minutes to practice the exercises before the pretest. The pretest took twenty minutes to accomplish but most of the research subjects were done before that.

On Friday 11th of May at 9.15–10.00 was scheduled for math lesson. Second part of the intervention was held in the same ICT classroom as the previous one. Same author was again responsible for planning and keeping the lessons. Same pairs were divided to the same workstations as on the previous day. The research subjects were taught briefly the meaning of decimals and fractions and the transformation between them, based on the results of the pretest. This took about ten minutes. After this, the research subjects did freely rounds 2, 3, 4, 5 (table 2) starting from round two. They had about 20 minutes to do this, while 15 minutes from the end of the class was reserved for the posttest. Everyone finished their test in time.

4.3 Analyzing the Data

Data gathered from the pre- and posttests were evaluated according to a standard created beforehand in the scale of zero to nineteen. Table 3 describes the descriptive statistics of the gathered data.

Table 3: Descriptive statistics of pre- and posttests.

	Pretest	Posttest
N	18	18
Mean	9.7222	13.7222
Median	9.5000	13.5000
Mode	14.00	11.00
Std. deviation	3.78551	3.67512
Skewness	-0.058	0.129
Kurtosis	-1.391	-1.063
Min	3.00	7.00
Max	15.00	19.00

As described in table 3, the whole class took part in the study, both in pre- and posttest. Tests were identical to keep the results comparable. The maximum score from the test was 19 points. No one scored zero points nor full points from the pretest, hence the test is a good indicator for learning results. The mean of the scores was on average four points better than in the pretest. Both tests' score distributions are approximately symmetrical and platykurtic. The latter is caused by two separate peaks in the data, signifying two different skill levels within the class.

In the first research problem, two measurements from the same individual are paired and compared. Therefore paired t-test is used to find out the significance level of these results. The normality of the score differences is evaluated with Shapiro-Wilk test. The same tests are also conducted and passed for the data without the points from exercises two.

Table 4 shows the descriptive statistics of subjective follow-up questions asked in posttest. Questions are freely translated as “How well did you manage to solve the given exercises?” and “What was it like to do these exercises?” The value of the answer is an integer on the interval 0–82, 82 being the best choice and zero being the worst.

The distribution of opinions on the computer-assisted learning method had clearly two peaks. The answers of four students were under 41 and eleven above it. The sample size was too small to make any statistically significant correlations between variables.

Table 4: Descriptive statistics of opinions

		How well did you manage to solve the given exercises?	What was it like to do these exercises?
N	Valid	14	15
	Missing	4	3
Mean		77.929	68.867
Median		82.000	80.000
Mode		82.0	82.0
Std. Deviation		6.5099	19.7443
Variance		42.379	389.838
Skewness		-1.627	-1.134
Kurtosis		2.287	-.743
Minimum		61.0	35.0
Maximum		82.0	82.0

5 RESULTS AND DISCUSSION

The results show how learning results developed over the intervention and how the research group felt about the computer-assisted learning. Results are gathered from pre- and posttest's and the overall scores of these tests are compared.

1. **What is the effect of collaborative learning, visualization and immediate feedback on the third graders' decimal calculation learning results?**

The statistical significance of the development in pre- and posttest values is presented in table 4. The research group increased their scores by four points on average, when total points were 19.

The development of pre- and posttest scores is statistically very significant ($p < 0,005$). The researcher taught the research group how to make transforms between decimals and fractions. The test included one exercise (exercise 2) measuring this skill. Table 5 also lists the statistical significance when this exercise is removed from the results. As seen in the table, the result is still statistically significant ($p = 0,002$).

Table 5: The statistical significance of the development of test scores between pre- and posttest.

	Mean	Std. dev.	t	df	p
Pretest - Posttest with exercise 2	-4.00000	2.42536	-6.997	17	**< 0.005**
Pretest - Posttest without exercise 2	-1.77778	2.01627	-3.741	17	**0.002**

Even though the sample size was small (N = 18) and the intervention length was only for one lesson, the results are in line with previous studies in the field of computer-assisted learning [15], [17], [33].

2. **The pupils' opinion on computer-assisted learning.**

As seen in table 4, the general opinion on computer-assisted learning is very positive. The range for possible answers in our questionnaire is 0–82. The mean of the answers is 68.867 and median 80. There are three missing values, because some answers were impossible to interpret. For example, one of the pupils answered by coloring a segment of the line instead of crossing just one point.

The teacher of the class commented during the intervention, that the pupils were very keen on doing the exercises. The researcher made also similar observations. However it is impossible to say whether the enthusiasm was caused by exercises or the different method of learning.

Based on writer's experience on teacher education in Finland, the educational applications used in schools are simple flash games or learning environments developed by the publishers. The most widely used learning environment in Finland is WSOY's Opit, which does not collect any information of student's interaction or results. Only collected information is about the applications student have opened. Khan Academy on the other hand has very similar exercises compared to the ones shown in this paper. It also saves the information about the results but lacks translations of the games and tutorial videos. Native language support is crucial to primary school learning and also later on, if students have any problems with the foreign language. Khan Academy also does not allow teacher to change any settings considering the games, thus there is no way for the teacher to personalize exercises.

This study sets an interesting stepping stone for future research with a control group and with a larger sample. The learning results and pupils' enthusiasm are encouraging and the possibilities of this kind of learning environment don't stop on pupils' learning. The learning environment also provides the teacher a great amount of information on pupils' learning and possible learning disabilities.

6 REFERENCES

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