E-Learning Sudan, Formal Learning for Out-of-School Children

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Abstract: E-Learning Sudan (ELS) is a custom-built computer/tablet game that provides alternative learning opportunities to Sudanese children who are excluded from education. Unique in ELS is that children can learn mathematics, in their own remote village, without a teacher. This research study assessed the effectiveness of ELS in two pilots through a pretest–posttest control group quasi-experimental design. In Pilot I, 67 children in three remote villages, used the game for a period of six weeks, five days a week, 45 minutes a day; the control group did not receive any education.. In Pilot II, 591 children in 19 remote villages, played the game for six months, for a maximum of five times a week, 45 minutes a day; the control group received informal education in out-of-school centers. The results of the analysis on the pretest–posttest data revealed that ELS increased mathematics knowledge acquisition in numeracy and adding significantly and maintained student motivation to learn. Analyses of control group data and EGMA (internationally validated Early Grade Mathematics Assessment) showed that the children in the experimental group learned more than children who received no education at all, informal or formal education. These findings suggest that the implementation of ELS can greatly benefit learning for out-of-school children like in Sudan.

Keywords: game-based learning, autonomous learning, primary education, mathematics, developing countries, evaluation

1 Introduction

As other Sub-Saharan countries, Sudan struggles with issues regarding access to education and educational quality (Mtika 2010; The World Bank 2012). The push to achieve the goal of educating every child at least to primary level (enshrined in the Millennium Development Goals and now the Sustainable Development Goals) puts pressure on educational systems which already struggled to cope with demand. Although the push towards universal access has substantially increased education enrollment, reaching those without access to school is a pressing issue, particularly girls and children in the rural areas in Africa and South Asia (Kallaway 2001; Cremin 2012). Equity still remains a major issue, not only involving girls, but also the poor, including linguistic and ethnic minorities, and other disadvantaged groups (The World Bank 2012; Kallaway 2001).

There are approximately 2.3 million children in Sudan not in school. At present, it is not realistic to believe that this will be solved through traditional means (schools and teachers). Due to the cultural, geographic and socio-economic background of children, more flexible, empowering and affordable approaches outside formal schools are required. The focus of this approach should be on rural areas, communities affected by conflict – including Internally Displaced Persons (IDPs)- and specifically include girls and minority groups. Online and distance learning with ICT are seen as possible solutions. Digital technologies, if the software is well-designed and the content grounded in a well-constructed curriculum, can deliver one-to-one interactive instruction, in a consistent manner, to all children. Children can learn at their own pace and repeat material as often as they need. The use of technology also allows for the individual monitoring of progress.

Promoting understanding of mathematics in the early years is critical, as longitudinal research has shown that early mathematical understanding is highly influential on later mathematics and reading performance at school (Duncan 2007), even after controlling for other basic skills that are known to affect school performance.

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This study reports the results of two pilots in which a gamified version of the Sudanese curriculum for mathematics for out-of-school children was tested. The mathematics curriculum comprises the learning goals for Grades 1, 2, and 3 and leads to an official certification (Stubbé in press).

Because this way of learning is completely different from the formal school system in Sudan a proof of concept was needed before the three-year curriculum could be developed into a game. The most important question that needed to be answered was if children can learn mathematics by playing the game. Following the 'fastest route to failure', a small part of the game (Pilot I: six weeks of the curriculum; Pilot II: six months of the curriculum) was developed and tested in remote communities in three states in Sudan.

Various meta-reviews and meta-analyses have shown the cognitive and motivational effects of serious games in general. In their meta-analysis of 32 studies in which traditional classroom teaching to computer gaming or interactive simulation were compared, Vogel et al. (2006) found an overall positive effect of serious games: significant higher cognitive gains and a more positive attitude towards learning were observed in subjects using interactive simulations or games versus traditional teaching methods. This seems to be the case for boys as well as girls, although the low number of studies that reported statistics for males and females gives reason to consider these results with caution. All age groups showed significant positive results for the use of computer gaming or interactive simulation. The type of activity did not appear to be influential; neither did realism of the pictures in the game. Wouters et al. (2013) investigated whether serious games are more effective in terms of learning and more motivating than conventional instruction methods. In their meta-analysis of 39 studies they found that serious games were more effective in terms of learning and retention, but were not more motivating than conventional instruction methods. Learners in serious games learned more than those taught with conventional instruction methods when the game was supplemented with other instruction methods, when multiple training sessions were involved and when players worked in groups.

Research on digital mathematics interventions has shown increased motivation (Rosas et al. 2003), more positive attitudes towards mathematics (Ke 2009), and a better mastery of mathematics (Praet et al 2014; Steenbergen-Hu et al. 2013; Li et al. 2010; Räsänen et al. 2009) for children in Kindergarten and primary education. All of these studies were conducted with European or North American children. Recently, Pitchford (2015) evaluated the effectiveness of a tablet intervention for mathematics in a school in Malawi. She concluded that tablet technology can effectively support early year mathematical skills in developing countries if the software is carefully designed to engage the child in the learning process and the content is grounded in a solid well-constructed curriculum appropriate for the child's development stage.

Clark et al. (2008) argue that the choice of media does not influence learning or media. Differences in instructional design prevail over the method of delivery. Usually the difference between passive and active learning and the clear and concise instruction determines variation in learning outcomes. This means that in the use of educational games the design of instruction delivered by these games is of crucial importance. This is in line with Wouters (2009) who argues that the alignment of learning outcomes and game type, the alignment of game complexity and human cognitive processes, attention for cognitive and motivational processes, research on specific mitigating effects, like gender, on game effectiveness should be considered in game design.

1.1 Acquisition of mathematical skills

Research shows that children develop mathematical skills at different levels before beginning formal schooling (USAID 2009). Children across cultures seem to bring similar types of skills to school, but do so at different levels (Guberman 1996). In general, children from low-income backgrounds begin school with a more limited skill set than those from middle-income backgrounds. This is related to the environment in which children grow up that enables them to understand the world, master language and get insight in the basic knowledge needed for mathematics (Greenman 2011). Furthermore, the rate of acquisition of mathematical skills can be influenced by the opportunities children have in their communities (Guberman 1996). Household tasks and chores can get in the way of developing these skills, but they can also enhance the acquisition of these skills because they provide meaningful learning opportunities (buying or selling vegetables). Once children begin formal education, they use this informal knowledge when completing new tasks (Baroody in Copely 1999; Ginsberg 1981).

Between the ages of 3 and 9, the construction of number knowledge develops in more or less the same ways (USAID 2009). Becoming efficient at mathematics requires the automatization of the subsequent stage, rather than repeating the earlier stages. Children need to free up cognitive capacity to be able to solve more complex problems (Pellegrino 1987). With continued practice, children become more confident in their computational and problem solving skills. This puts a significant emphasis on good early mathematics experiences for children.

Across countries, curricular and conceptual goals show similar subjects (USAID 2009):

- developing an understanding of whole numbers, including concepts of correspondence, counting, cardinality, and comparison;
- representing, comparing, and ordering whole numbers, and joining and separating sets;
- developing understandings of addition and subtraction, and strategies for basic addition and subtraction facts, including whole-number relationships (e.g. tens and ones); and
- developing understanding of base-ten numeration system and place-value concepts, including fluency with multi-digit addition and subtraction.

This means that a mathematics game aimed at the first three grades of primary school, should comprise at least these subjects.

1.2 Game design

The design of the game and its requirements are described in more detail in Stubbé et al. (in press), but this paragraph will provide a short summary. The most important constraint for the game design was that children will use the game in their own remote communities. This automatically implies that there will be no school or teachers. Instruction and feedback will therefore have to be incorporated into the game. Because this project focuses on vulnerable children with little learning support from parents or teachers, we assume them to have little informal knowledge. Besides, the opportunities to learn from everyday life situations in the communities are scarce. Because of this the approach for struggling learners is followed. One of the major issues in supporting struggling learners is to ensure that there is a strong basis to build on. This corresponds with the concept of mastery learning (Bloom 1985), where 'the students are helped to master each learning unit before proceeding to a more advanced learning task'. Furthermore, struggling learners need explicit instruction (Timmermans 2005; Milo 2003). Research (Bodovski 2007) shows that struggling learners show less engagement during instruction. If this engagement is increased, performance increases as well. A focus on 'time on task' (Carroll 1963) could help to improve learning results; for all children can learn mathematics, but some need more time than others. This means that the game should provide active learning, motivate children to increase their time on task, and use individual, continuous assessment in order to provide each child with mini-games that match the level of mastery. In addition, special attention will need to be given to the specific context in which the children live, to avoid children using too much of their cognitive capacity for processing (narrative) information that is not directly related to the learning content (Wouters et al. 2013).

Instruction is provided by short videos (1-2 minutes) per mathematical concept (Figure 1). In the videos, slightly older children, aged 14-15, explain the mathematical concept and show how to approach problems relating to this concept. This has a motivating effect, and helps the children to understand what they need to do. The language used is simple Modern Standard Arabic, which makes it possible for children to understand the instruction, and, therefore, understand the mathematical concept. Children must watch the video once, to introduce a new mathematical concept. Then, they can watch it as many times as they like.

Figure 1: Screenshot of instruction video

Figure 2: Screenshot of feedback in mini-game

Children receive immediate feedback on the answers they give (Figure 2). This helps them to know if they are on the right track. The testing underlying this feedback is also used as continuous assessment to determine progress in the game and make sure children always learn at their own level. In addition, feedback on progress is given in two different ways: the children receive stars when they have finished mini-games, and proceed to a next level when they have finished the previous one. The curriculum in the game starts with Kindergarten learning goals. In this way, all children are given the opportunity to build a strong basis before continuing to more complex mathematical concepts. Each mathematical concept can be practiced by a number of different mini-games. First of all, this enables active learning: children are actively engaged in solving mathematical problems. In addition, the diversity of games motivates them to spend more time on practicing a mathematical goal. They feel they are doing different games, while they are, in fact, practicing the same mathematical concept. Last but not least, much attention was given to make the game context specific. For this, children in the remote communities in Sudan were asked to draw their own environment: clothes, food, animals, plants, and family. These drawing were used as a basis for the graphic design. The overall narratives (helping other children to become e.g. a goat herder; a shop where product are bought and sold) fit in with their cultural background. Because children recognize the objects and the narrative, their cognitive capacity can be dedicated to learning the mathematical concepts.

2 Method

This study reports two pilots. Both pilots used a pretest-posttest control group quasi-experimental design. Participation.

In the communities, all children in the relevant age group were invited to participate in the experiment. Parents were informed about the goal and the method. The community was involved in setting up the 'learning centers' (sheds where the children gathered to learn). Children were assigned to either morning or afternoon learning sessions, according to their parents' wishes. In this way learning could fit in with their chores and household tasks.

Learning Sessions and Hardware

Because there were two learning sessions a day, the hardware could be shared. Each laptop or tablet was used by two different children. Consequently, hardware stayed in the learning center, locked away until the next session.

Facilitator

Each community had a facilitator. The facilitator encouraged the children to work with the mathematics game and helped with technical problems. The facilitator was not supposed to teach or explain the principles of mathematics. Facilitators were trained to take this role and to solve technical problems. During the week, they lived in the communities, in the weekends they could go home.

Observer

During Pilot I, observers attended the learning sessions twice a week, to observe if the facilitator followed instructions. In both pilots they tested the children with respect to their mathematical knowledge.

Staggered approach

A staggered approach was used to support the start in each community by the observers and supervisors. Moreover, the technical issues that arose in the first community could be solved before the other communities started. The control groups were tested later.

Oral test

Oral mathematics tests were used because all children were assumed to be illiterate (Pilot I: test A; Pilot II: test A & B). These tests were designed on the basis of the Early Grade Mathematics Assessment (EGMA, USAID 2009), and consisted of 30 items each (maximum score was 60 points), covering the very basics of mathematics. Both tests tested oral counting, number identification, one-to-one correspondence, quantity discrimination, word problems, addition and writing down numbers. In test A the numbers ranged from 1 to 10, in test the numbers ranged from 1 to 20. The same tests were used as a pretest and posttest.

Test protocol

As the children live in remote communities, it was assumed they had not been tested before in any formal way. Reports on the testing of children in developing countries mention that children are shy to answer any questions at all (Kanu 2013). A test protocol was designed, including child-friendly approaches. The observers were trained to use this. During testing, a supervisor was present to ensure that the testing was performed according to protocol.

Ethics

The ethics committee of the Ahfad University for Women in Khartoum has approved these pilot studies. In addition, agreements have been signed by White Nile State, North Kordofan State and Gedaref State and the participating communities. All facilitators signed a child safety protocol. Parents have signed consent forms for their children to take part in the experiment and to be photographed. All data are related to a child-specific number. This was done for privacy reasons, as well as for pragmatic reasons (Arabic names can be spelt in different ways in English). The communities in the control group in these pilots, will participate in a later phase of the project.

2.1 Pilot I

Participants were 67 children in three remote communities in Sudan (Mona, OmTifag, and Wad Almoshmer), aged between 7-11. See Figures 3 and 4 for percentages per gender and age. The control group consisted of 19 children in a fourth remote community (OmOkaz). None of the children had been to school before. The experimental group used the laptop game for a period of six weeks, five days a week, 45 minutes a day, while supervised by a facilitator. The control group did not receive any education in the same period. In addition to the test results (test A, pretest and posttest), the following data were collected: attendance, motivation (observed by facilitator) and the logged data in the mathematics game. At the end of the pilot the children were tested by a nearby school, to assess their Grade level.

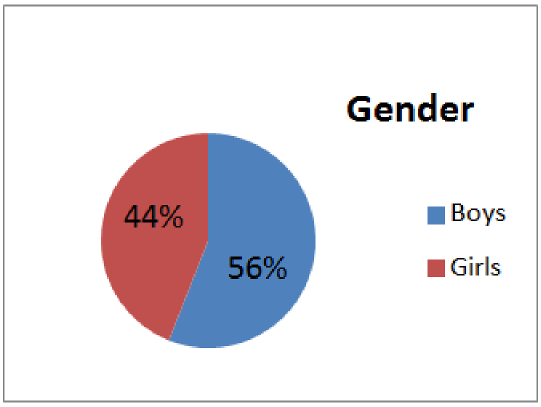

Figure 3: Percentage of children per gender

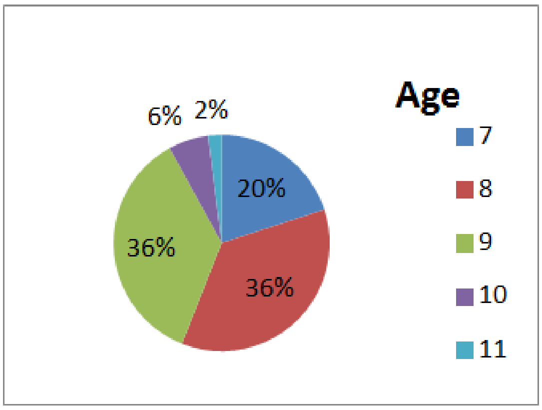

Figure 4: Percentage of children per age

Three children were excluded from the experimental group; two because they had been to school before, one because he had been brought from another community and became homesick after only three days. Three children did not take the post-test, seven others dropped out during the pilot. The data from the remaining 54 children was used for analysis. In the control group no children were excluded from analyses.

There was one technical problem in the first week in the first community. Because the game depends heavily on audio and video, children needed earphones to be able to hear the instruction from their own laptop. This was arranged within a week. Furthermore, there was a software problem: the first four levels in the game were adequately developed. For the fifth level, the instruction video had not been included, which made it difficult for the children to understand what they needed to do in that level.

Although unique numbers were used to ensure anonymity, some observers only wrote down the names of the children. Because of the many ways in which Arabic names can be written down in English, it was hard to match the collected data for nine children. In collaboration with the observers, the names were matched with the unique numbers.

2.2 Pilot II

Participants were 591 children in 19 remote communities in three states in Sudan (White Nile, North Kordofan and Gedaref), aged 7-9. The control group consisted of 325 children in 10 more remote communities in the three states. The experimental group used the tablet game for a period of approximately six months, for a maximum of five days a week, 45 minutes a day, while supervised by a facilitator. The children in the control group were enrolled in informal education; they attended two mathematics lessons a day of 45 minutes each, taught by a teacher in out-of-school centers. In addition to the mathematics tests A and B, the internationally validated Early Grade Mathematics Assessment (EGMA) was taken by independent consultants, with a stratified sample of the children (210) in the experimental condition. Finally, logged data were collected from 532 accounts.

Figures 5 and 6, below, show the percentages per gender and age.

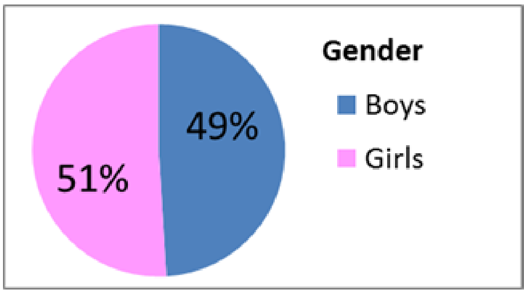

Figure 5: Percentage of children per gender

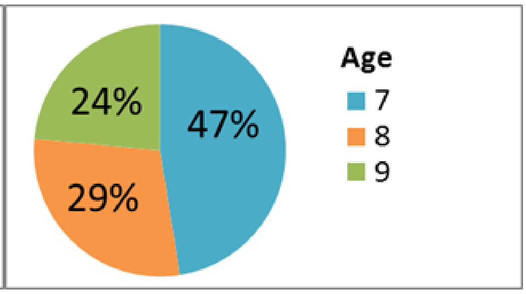

Figure 6: Percentage of children per age

Three children were excluded from the experimental group; one because he was too young (6 years old), two because they had been to school before. Facilitators reported that 57 children dropped out during the pilot. Five more children were excluded on the basis of the logged data: their logged data showed they had only played the game for a short period, and not finished it. The data of the remaining 526 children was used in further analyses. There were, however, some issues with the data collection in the control group: the pretest and posttest were not taken at the designated times. In Gedaref, the pretest of test A was taken two months after the children had started their lessons. Because of this, all data from the Gedaref control group (100 children) was excluded from further analysis. In White Nile and North Kordofan, the pretest of test A was taken at the right time; the posttests, however, were taken later than planned. Instead of an interval of 6-8 weeks, the posttest was taken after three months in North Kordofan (45 children) and after six months in White Nile (180 children). Consequently, the results from these two states were analyzed as two different sets. There were no posttest data for 14 children in North Kordofan and for 34 children in White Nile. The data of the remaining 177 children was included in further analyses. Because of logistic issues, logged data were not collected for two communities (57 children). Also, the matching of logged data to the test data proved difficult, because the facilitators had not used the unique child numbers for this, but had instead used the child's name. Because names in Arabic can be spelled in different ways, it was impossible to match 23 files of logged data. For 449 of the children in the experimental condition logged data were available and included in further analyses.

Because of the iterative development process used, two updates of the game had to be installed during the pilot period. The progress in the communities in North Kordofan, who started first, was faster than anticipated: they had to wait two weeks before the first update could be installed. Furthermore, two mini-games did not function properly which made it impossible to give the right answers. These bugs were fixed within two weeks.

In general, communities had two facilitators, taking turns supervising the learning sessions. In White Nile,however, there were four communities in which the only facilitator left in November 2014, and the new facilitator(s) started in January 2015, leaving a one to two-month interval during which learning sessions were not supervised.

3 Results

3.1 Pilot I

Pilot I was conducted in the period of December 2012 to February 2013.

There were more boys than girls, in the experimental condition (56%-44%) as well as in the control group (60%-40%). This reflected the situation in the communities; girls were not excluded from the pilot. There was no significant difference in participation of girls and boys between the experimental communities and the control group.

The children's ages varied between 7 and 11, with most children at the age of 8 and 9 There was no significant difference between the average age in the experimental condition and the control group (8.3).

The experimental group had an average of 33% correct answers on the pretest (N=67, M=20.3, SD= 11.5). The control group had an average of 28% correct answers on the pretest (N=19, M=16.5, SD= 5.6). An independent T-test showed no significant differences on the scores of the pretest between the experimental group and the control group (t=-1.4283, df=79, p=0,16). The average score of the experimental condition on the post-test was 55% correct (N=54, M=33.1, SD=15.5), the control group showed a slight increase to 29% correct answers (N=19, M=17.2, SD=5.3). An independent T-test showed a significant difference between the posttest scores of the experimental condition and the control group (t=-4.5059, df=79, p=0.00). Furthermore, an independent T-test showed significant differences on the delta scores (posttest-score minus pretest-score) between the experimental group and the control group (t=9.1, df=71, p=0.00) (see Figure 7). Hence, the experimental group has learned significantly more than the control group.

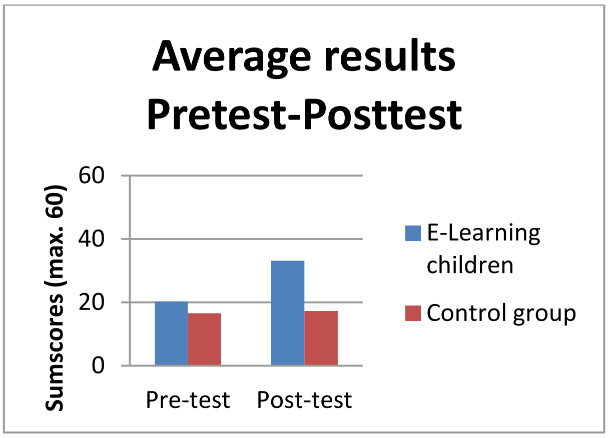

Figure 7: Results pretest-posttest

All the children that used the game improved significantly, but children with a lower score on the pre-test, increased their scores more than children with a higher score on the pre-test. The increase varied between 9 and 42 points. There were no significant differences between boys and girls or between age groups.

3.1.1 Logged data

The logged data show that with a few exceptions all the children used the game five days a week during the pilot period. Approximately 30% of the children completed all the materials in the game. The other 70% of the children finished between 50-70% of the materials. The children that had finished before the pilot ended were told to start again from the beginning.

3.1.2 Observations

Observation forms were filled out daily by the facilitators. They show most children were present during sessions and were motivated to learn most of the time (see figure 8). There were differences in motivation between communities at the start of the experiment, but average motivation increased over the six weeks (from 2.7 to 3.2 on a 4-point scale). In Mona motivation decreased during the first week. This could be explained by the fact that the children did not have headphones, and could not hear the instruction. After this was solved, motivation increased again. In Wad Almoshmer, motivation in the first week was at a maximum. Later, motivation decreased towards a more average level.

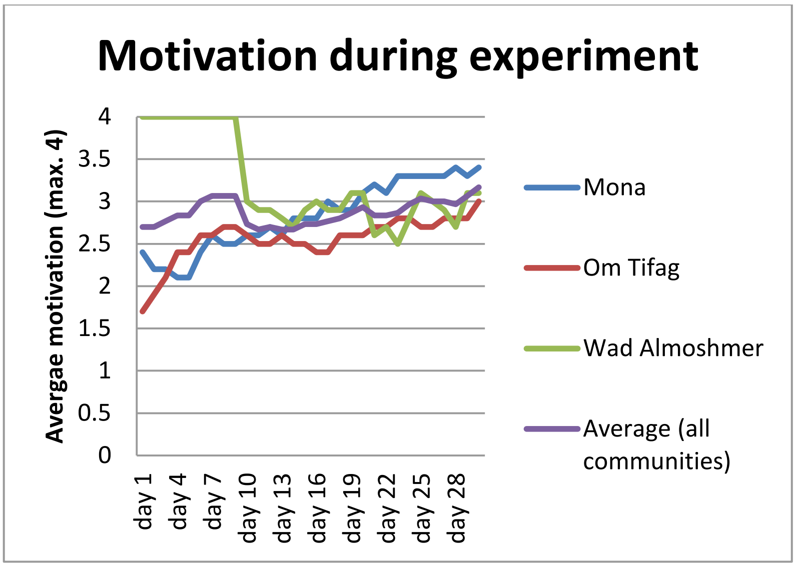

Figure 8: Motivation during pilot I

The children said they loved the instruction videos very much, and some watched them twenty times. When asked about this, they would say that the older children in the videos were their big brother or sisters (role model); 'If she can do it, I can do it as well!' They also loved the many games and the colors in the game.

One of the participating children was a physically handicapped boy . Because of his slurred speech, people thought he was retarded as well. He performed very well with an average improvement of 15 points. He is now more accepted by the other children, and even his speech has improved.

After the six-week experiment the children were taught by teachers in their own community for the rest of the school year. At the end of this period they were tested by a nearby school. Ten children were admitted to Grade 4, five children were admitted to Grade 2 (which would be normal progression) and the rest was admitted to Grade 3. The progress of the ten children admitted to Grade 4 was followed carefully. At the end of Grade 4 they were the top 10 of their year. This shows that the children not only learned their mathematics, but also formed a strong basis for further development.

3.2 Pilot II

Pilot II was conducted in the period of October 2014 to March 2015. Participation of boys and girls was almost equal (49% vs. 51%). The average age of the participating children was 7.8 years. Children in North Kordofan were slightly younger (average is 7.4 years), compared to the children in Gedaref (8.0 years) and White Nile (7.9 years). Analysis of the demographic information of the children who dropped out showed no significant effect for gender or age.

3.2.1 Test results

To assess if children have increased their scores on test A an Anova repeated measures (SPSS GLM) test within subjects factor: Math-A-PRE en Math-A-POST was used. On average children in White Nile, North Kordofan and Gedaref had 33% correct on the pre-test of test A (20 of a max. of 60 points). The average on the post-test of test A was 68% correct (41 points). This increase is significant ($F(1,499)=1170.929$; $p< .001$); $r=.85$). There were significant differences between the states ($F(2,99)=21.710$; $p < .001$; $r=.29$); White Nile has a higher score than North Kordofan and Gedaref on the pre-test (24 points resp. 16 resp. 19) as well as on the post-test (47 points resp. 40, resp 37) of test A. Posthoc tests (Bonferroni) show that White Nile differs significant ($p < .001$) from the other two states. There is also a significant interaction between Math and State $F(2,499)=9.055$; $p < .001$; $r=.21$). All three states perform better on the Post-test than on the Pre-test, but North Kordofan has a relative greater increase of scores from pre-test to post-test. This can be explained by the significant differences between age groups, with older children having higher scores than younger children ($F(2,499)=14.758$; $p < .001$); $r=.25$) (see Figure 9). The average age in North Kordofan was lowest, in White Nile children are older.

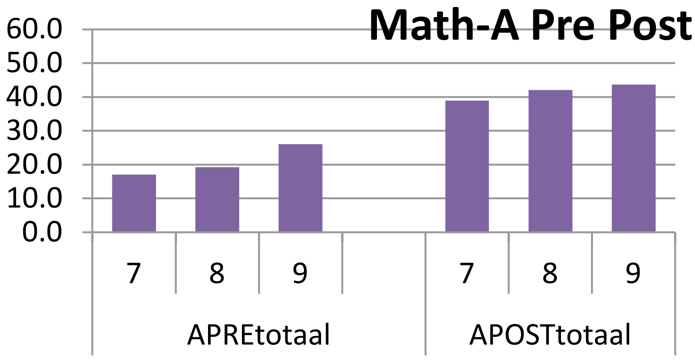

Figure 9: Average score test A pre-post per age.

Also, children with a lower score on the pre-test showed a larger increase in scores than children with a higher score on the pre-test (F=29.17, hypdf=2 errodf=488, p<.00, eta=.11). This can partly be explained by a ceiling effect: if children have a higher score on the pre-test, there is less room for improvement. In addition, the first levels of the game addressed more basic mathematical concepts. If children already mastered these, they could not learn much in these levels. There were no significant differences for gender: scores as well as increase of scores were similar for boys and girls.

Because of the data collection issues with the control group regarding the timing of testing, differences between the experimental group and the control groups must be interpreted with caution. Comparisons are made per state, not with the total average scores. A comparison of the North Kordofan (NK) experimental group with the NK control group shows no significant differences, in pre-test, post-test or increase of scores between pre- and posttest (see Figure 10). This is a positive finding, as the NK control group received twice as much instruction per day, compared to the experimental group (2 times 45 minutes, vs. 45 minutes a day). Moreover, the NK control group had a three month interval between pre- and posttest, whereas the experimental group had a 6-8 week interval between tests. Roughly, the NK control group has had three times as much opportunity to learn as the NK experimental group. The NK control group is very small (N=31), which makes it less suitable to compare to the NK experimental group (N=182).

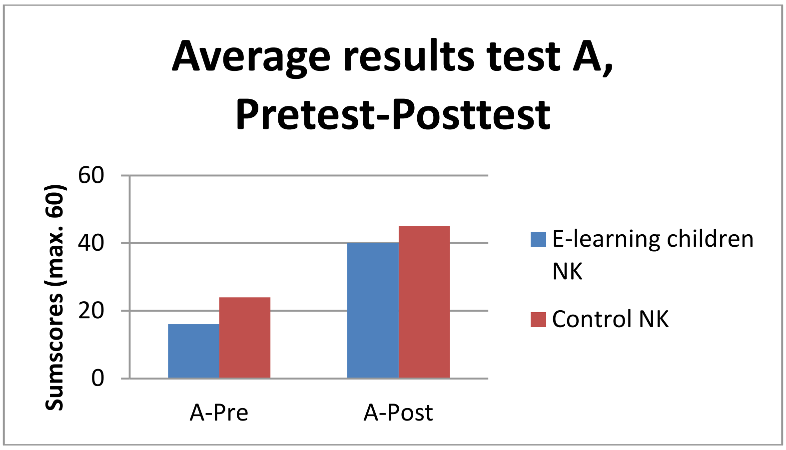

Figure 10: Average results test A, Pretest-Posttest North Kordofan

A comparison of the White Nile (WN) experimental group (N= 148) to the WN control group (N=146) shows that there is a significant difference in increase (31 vs 36 points) between the two groups (F(1,288)=17.034; p < .001; r=.24). The WN control group on average significantly increased its score more than the experimental group (see Figure 11).

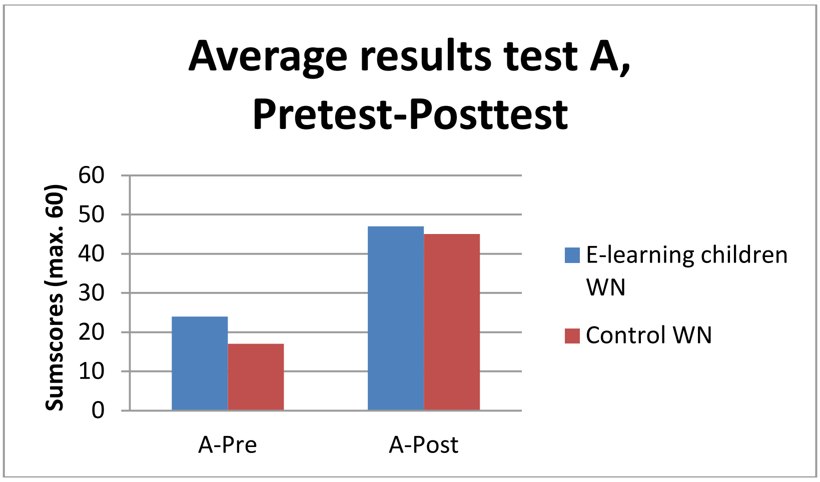

Figure 11: Average results test A, pretest-Posttest, White Nile

It is important to note that the WN control group had (much) more opportunity to learn: they had two mathematics lessons of 45 minutes per day versus 45 minutes in the WN experimental group, and a much longer interval between pretest and posttest (6 months vs. 6-8 weeks). This means the WN control group had roughly six times more learning time than the children in the WN experimental group. The WN control group had 75% correct on the posttest, which means that there was more room for improvement. From this perspective, the difference in increase of scores is rather small. Children in the WN experimental condition have relatively learned more.

To assess if children have increased their scores on mathematics test B an Anova repeated measures (SPSS GLM) test within subjects factor: Math-B-PRE en Math-B-POST was used. The average score of children in White Nile, North Kordofan and Gedaref on the pre-test of test B was 32 (max. 60). The average score on the post-test of test B was 41. This average increase of 9 points is significant ($F(1,456)=160.067$; $p < .001$; $r=.51$). There were no significant differences for gender (see Figure 12) and age groups.

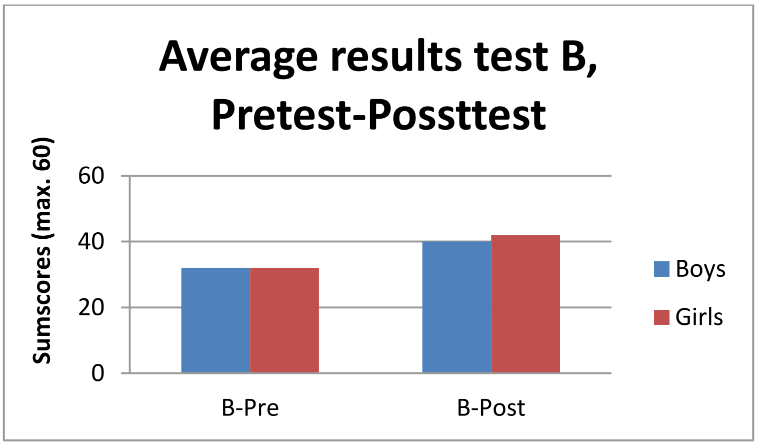

Figure 12: Average results test B, Pretest-Posttest for gender

The pre-test score is remarkably high. This can only partly be explained by the overlap between test A and test B. In the research plan, the pre-test of test B should have been taken at the same time as the post-test of test A. In reality it was taken later. In the meantime children played on, and thus increased their knowledge. This may explain the high average on the pre-test of test B.

Because the order of the curriculum in the game was different from the Sudanese curriculum used in the out-of-school learning centers, the control groups did not take test B: they had been taught the mathematical concepts tested in test B.

3.2.2 Results EGMA

The results of EGMA, taken by 210 of the children in the experimental condition, can be compared to earlier studies with Arabic speaking children in Khartoum and Jordan, because it is an internationally validated test. Figure 13, below, shows that the children in the experimental condition (ELS) had the highest percentage correct in three sub-tests of EGMA (Shapes I, Shapes II and Word problems) after only six months of learning, compared to children who had attended school for 2.5 years in Khartoum and Jordan. In a fourth sub-test (Missing number) the children in the experimental condition had a higher score than the children from Khartoum. The children in the experimental condition only had a slightly lower score on: Number discrimination, Addition level 1, and subtraction level 1.

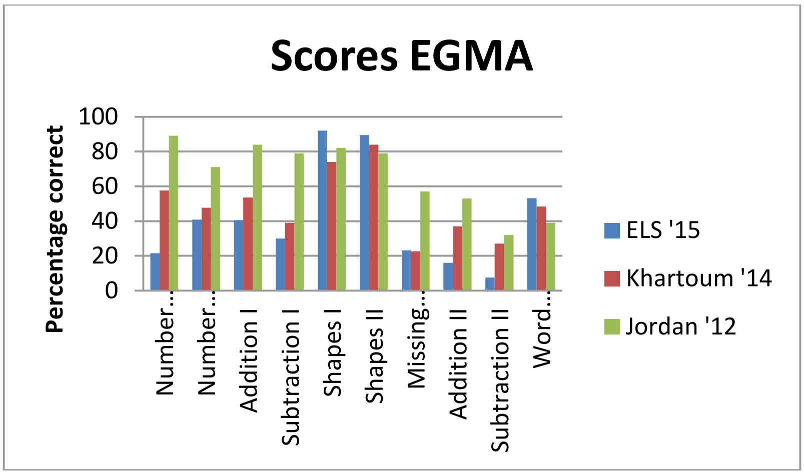

Figure 13: Scores EGMA compared; E-Learning children (ELS), Khartoum and Jordan

There are significant positive correlations between the scores on the mathematics tests A and B (pre and post) and the measurements of EGMA. These correlations are not always strong. The strongest correlations are for Addition level 1, Subtraction level 1 and Problem solving, all correlating more than .50. Although all tests show significant positive correlations with EGMA, the B-Posttest has the strongest correlations. This can be explained by the fact that test B measures more difficult mathematical concepts than test A, and is, therefore, more similar to EGMA than test A. These correlations show that test A and B measure similar concepts of mathematics as EGMA.

3.2.3 Logged data

Most of the children played the game for a period of 5 to 7 months (average 135 days). Girls were found to participate for a longer period than boys (average of 141 versus 129 days; $F(1,378) = 7,726$; $p < 0,05$). No differences were found for age. Children from North Kordofan played a significantly shorter period (122 days), compared to White Nile (138 days) and Gedaref (145 days; $F(2,377) = 11,114$; $p < .001$). Correcting for both gender and age, children were found to only differ in the number of days between first and last play based on state ($F(2,363) = 6.123$; $p < .05$).

On average, most children were found to participate two to three times a week. Figure 14 represents the frequency of playing (average plays per week), in categories. No differences were found for gender. Age was found to be significantly related to frequency of playing: 7-year olds played more often (2,7 days a week) than children 8-year olds (2,3 days a week), who in turn played more often than 9-year olds (2,0 days a week; $F(2,377) = 17,909$; $p < .001$). There was also a difference between states: children from North Kordofan played more often (3,2 days a week) than children from White Nile (2,2 days a week), who in turn played more often than children from Gedaref (1,7 days a week; $F(2,377) = 143,954$; $p < .001$). Correcting for both gender and age, children were found to only differ in the frequency of playing based on state ($F(2,363) = 80.093$; $p < .001$). Frequency of playing is an average that can be the result of playing five times a week for a number of weeks and then skipping one or more weeks, or playing a limited number of days per week.

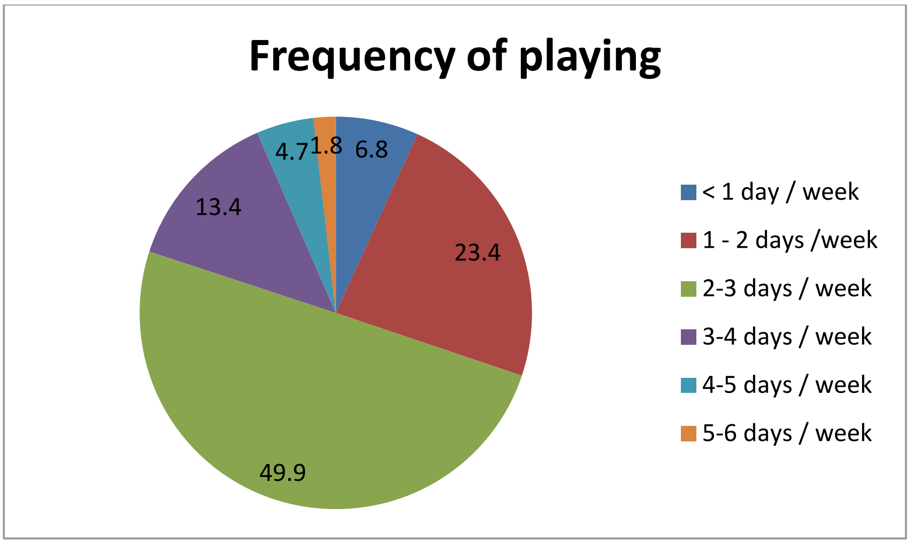

Figure 14: Frequency of playing

Although there is a correlation between the number of times played and percentage of the game completed, test results are better for children who participated for a longer period, even if their frequency of playing was lower.

4 Discussion and conclusion

In this study we aimed to test if children in rural areas in Sudan could learn mathematics autonomously, by playing a mathematics game on a computer or tablet, only supervised by a facilitator. To assess the effectiveness of the game two pilot studies were conducted. Pilot I tested a small part of the curriculum (6 weeks) with 67 children playing the game five times a week, 45 minutes a day, supervised by a facilitator. Learning sessions took place in the remote communities. Pilot II tested a larger, and more diverse, part of the curriculum (6 months) with 591 children playing the game 45 minutes a day for a maximum of five days a week. In a baseline study the mathematical abilities of children were assessed. After approximately 6-8 weeks children were reassessed so that learning gains could be determined. In pilot II two tests were used, both with a 6-8 week interval.

Educational research in remote areas in Sudan proved to be a challenge. Although facilitators and observers had been trained to use the test protocol, tests were not taken at the designated times. As a result the pre-test of test B was taken too late, leading to rather high scores on the pre-test. This makes it harder to show significant improvement. Using control groups in developing countries is also an issue: there is an ethical element in asking communities to participate in a pilot as a control group without allowing them to benefit from it. In addition, agreements have to be signed at various levels before communities can participate. As a result the control groups were smaller than the experimental group. Again, in the control group tests were not taken at the designated times, leading to an exclusion of the Gedaref control group, and modified analyses for the NK and WN control groups in Pilot II.

Nevertheless, this study showed that using the mathematics game was more effective than no education, informal education and formal education (for the sub-tests taught in the game) for primary school children in Sudan. In both pilots, all children in the experimental condition have improved their scores on mathematics tests significantly. In pilot I, the control group who received no education did not improve their scores during the same period. This proves that the increase in mathematics scores in the experimental was not caused by maturation or a test effect - as a result of taking the same test within six weeks - but by playing the game. In Pilot II the control groups showed the same or slightly more improvement, despite the fact that they had received three to six times as much opportunity to learn than the children in the experimental condition. To ensure external credibility, independent, trained consultants took the standard Sudanese version of EGMA with a stratified sample of the experimental group in Pilot II. The results show that the children in the experimental condition, who had used the game for approximately six months, had higher scores on three sub-test of EGMA than children in Khartoum and Jordan who had been to school for 2.5 years. On a fourth sub-test the children in the experimental condition had a higher score than the children in Khartoum. This shows that children can learn from the mathematics game, with only a facilitator to supervise them. There was no significant difference between boys and girls; the game is as effective for girls as it is for boys.

It is important to realize that the children involved in these pilots had never been to school before. In addition, 80% of their parents have never finished primary school and are functionally illiterate. Although mathematics games have been tested in developed countries (Praet et al. 2013; Räsänen et al. 2009), and even in schools in developing countries (Pitchford 2015), this is the first time a mathematics game was tested with this specific target population: out-of-school children in remote areas without any access to school, teachers or learning materials. Representatives of the Ministry of Education in Sudan who have visited the communities during the pilots, and the consultants taking the EGMA test with the children expressed their surprise at how much the children were learning and how confident they were about their knowledge.

In general, children with a lower score on the pre-test of test A improved more than children with a higher score on the pre-test. This is probably due to a ceiling effect: the game and the test focused on the very beginning of mathematics. Children that already had some knowledge of mathematics, achieved a higher score on the pretest and thus had less room for improvement. In addition, the game taught the basics of numeracy and addition. Children who knew how to do this could not learn very much from the game. They were the ones that went through the initial mini-games quickly. Others took longer to understand the basics of numeracy. Since the game offers children the possibility to learn at their own pace, they would always be playing mini-games that suited their level of mathematical skills.

During Pilot I children played the game for six weeks, five times a week. Pilot II was organized similarly: facilitators provided learning sessions for six months, five times a week. However, the logged data showed that the majority of the children only played an average of two to three times a week, thus decreasing allowed learning time by almost half. Although the learning results would probably have been better if children had participated five times a week, progress was still good. This shows that the use of the mathematics game allows children to learn at their own pace: if they skip learning sessions for a day or a week at the time, they can always come back and continue where they left off. In a more formal classroom environment this would be very difficult; children would have missed instruction.

When children learn autonomously, without a teacher to give instruction and feedback, and motivate them, there is always the issue of motivation. Will they stay motivated to keep on learning for a longer period of time? During Pilot I average motivation stayed high, and increased slightly. During Pilot II, focus group meetings were organized with children and parents. In discussions, both groups indicated that they liked learning and playing the game very much.

The most important goal of this study was to prove that children can learn from playing the mathematics game. As this method of learning is completely different from what is generally used in Sudan, a ‘proof of concept’ was needed before the rest of the game was developed. Both pilot studies have shown that children can learn, autonomously, using the mathematics game. Tablet technology, including well-designed, curriculum-based, engaging software, could help reach the 2.3 million out-of-school children in Sudan and teach them the basics of mathematics. Although teachers play a very important role in children’s learning and children should attend school, this game can provide learning for those who have no access to school (yet).

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