Socialising Mathematics: Collaborative, Constructive and Distributed Learning of Arithmetic Using a Chat Application

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We report an exploratory study that examined the educational possibilities through a verbal messaging application (chat), and show that this activity has the potential for effectively teaching mathematical concepts. Communicating in a virtual chat room allows children to become literate, as well as situate themselves in a social environment. Because of the latter possibility, children look forward to this activity with lot of motivation and interest. We modified some rules of the virtual chat room in the Sugar Learning Platform to facilitate development of arithmetic skills like addition, subtraction and multiplication. We present the highlights of this chat room experiment, and outline the insights gained from the analysis of the logs collected over five months from a group of 15 tribal village students (3rd and 4th grade).

Introduction

In a regular Indian classroom, we expect children to become literate, but generally we do not allow them to speak or communicate with each other. In a technology-aided classroom, however, the barriers to interpersonal communication breaks down. Chat is an example of an application that allows the children to communicate. At the classroom level, chat can be used to create peer collaboration and competition. At the individual level, it allows some cognitive processes to be distributed to the physical world, as elements usually recorded in working memory are recorded on the computer screen. This offloading reduces cognitive load and makes collaboration, tracking and feedback more reliable. However, chat introduces the requirement of writing everything down. We present a game that exploits these features, to create a learning, teaching and assessment studio. This study explores what works and why, what doesn't work, and what needs to be added into the chat activity that comes bundled with the Sugar platform to be affective as an educational tool.

We only report qualitative results in this paper, as the analysis of the chat logs is ongoing. Our focus here is a distributed cognition (DC) analysis of the key features of a chat game we have developed. Section 2 provides an overview of the study and qualitative results. Section 3 presents a DC analysis of our chat-based game. We argue that the chat application creates conditions for the social learning of mathematics, which, although is not a popular approach in the teaching and learning of mathematics, shows potential.

Computers in the Wild

The Infrastructure

Our study used a chat application running on a One Laptop Per Child (OLPC) [1] machine. These strong and rough laptops (called XOs) are created specially for children. The chat application is part of the Sugar Learning Platform (SLP) [2], an activity-centered, GNU-Linux based desktop, inspired by a constructionist approach (in contrast to an instructionist approach) to education (Papert, 1993). The XO and the SLP are built by non-profit foundations that do research and development work on using information and communication technologies (ICT) for inclusive education.

Every application in SLP is called an activity, and chat is one among many activities provided by the platform. It is like any other chat application, except for the following key differences. One, it does not need an internet connection, as XOs can directly connect with each other through an ad hoc radio protocol. Second, it shows every participant's entry in different colors of their own choosing. Third, the machines can be named, and the

1 http://laptop.org

2 http://sugarlabs.org

machine names are displayed in the chat (Our machines were named after elements in the periodic table, such as Magnesium, Carbon, Sulphur etc.). We exploited these features to make the chat activity similar to a game.

School and Participants

Our study was conducted in a remote village school in India. The tribal village (Khairat-Dhangarwada in Maharashtra state) has a government primary school where children can study up to 4th grade. Students from three different vadis (hamlets) come to this school. It is a full-day school, starting around 8:30 am and ending around 4:30 pm. The school has 26 students. All of them were given laptops (XOs) by the OLPC Foundation. For the current study, only the 3rd (n=3) and 4th (n=12) class students were selected. Almost all the children in our sample were first-generation learners. With the exception of one or two children who got help at home for studies, the students in our sample did not get any learning support outside of the school. The students' parents either worked in farms or as labourers. Some went to the nearest town for work. The school has two teachers, who teach two grades each. The school's medium of instruction is Marathi. The laptops support Marathi (Devanagari) script, and activities were translated into Marathi. The keyboard also had English and Marathi script printed on it, so that the students could type in Marathi. Elder children (3rd and 4th grade) took their XOs home. The school has a charging station, where the children charged their XOs during lunch break. They were also provided personal chargers at home.

Research Design

Our study ran for five months, and was based on a modified version of the standard one group pre-post quasi-experimental design. The significant modification was that most of the chat sessions doubled up as both tests and instruction (construction), and therefore post-testing was ongoing as the posted messages were used as a source of continuous assessment. Field-notes and computer logs were collected during the intervention. We conducted semi-structured personal interviews to assess students' knowledge before the intervention, and similar interviews were done to check their knowledge after intervention. In both the interviews we checked students' performance in a identification-of-number task (up to three-digit), addition task (up to three-digit) and subtraction task (up to three-digit).

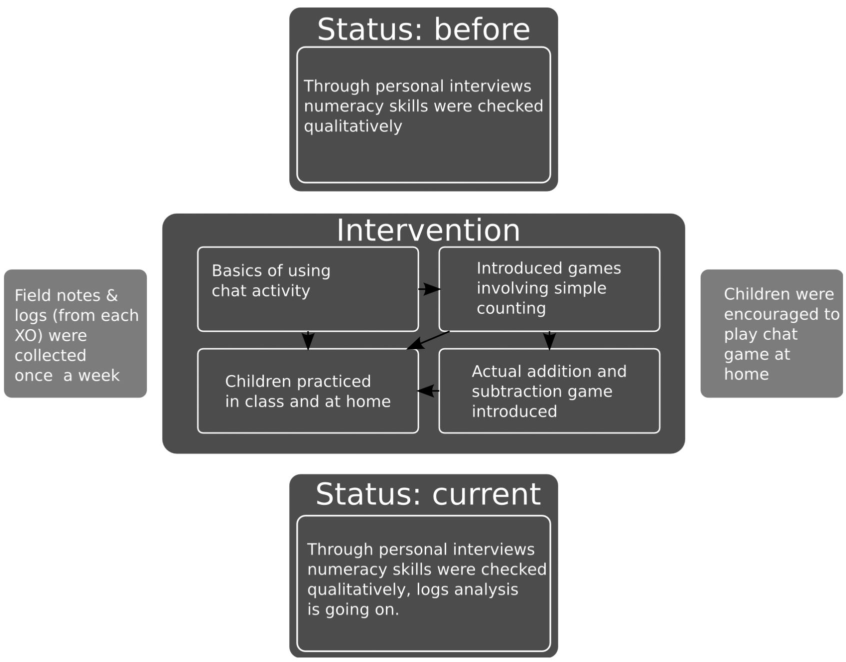

Figure 1. Design of the Study

Figure 1 shows the research design of the study. In the first phase, we taught students the basics of using the computer, as well as the chat activity (although some of them were already familiar with it). In the next phase, we introduced simple games using chat activity, such as counting forward or backward from a given number (e.g. 1, 2, 3, 4, 5,... 100 or 100, 99, 98,..., 1). The aim was to make the students comfortable with the chat activity. During the early phase, the students used to show us their laptop screen when they posted something, not realizing that everyone sees their texts as soon as they post a message. It took a while for them to understand that all screens displayed the same information, and the teacher could also see whatever they were seeing on their screens.

After this phase, we introduced addition and subtraction games. During each phase, students were encouraged to practice what they learnt. Figure 2 shows a typical instance of the chat game (detailed description in section 3.1). Logs from each XO were collected once a week.

Pre-intervention test results

The personal interviews sought to understand the students' reading and writing skills, as well as their numeracy skills. We found that their numeracy skills were very poor. Except for three students, others were able to count up to 100, but eight of these students were not able to identify or write a random two-digit number posed by the researcher. Three students made similar mistakes. When they were asked to write 370, they wrote 30070, a standard mis-conception known as hundred-tens conception (Fuson et al, 1997). They were able to perform simple addition tasks with single-digit or two-digit numbers, without carryover. Five students were not consistent while doing this task. Only one student was able to add three- digit numbers (without carryover). Similar results were seen in the case of subtraction. All students' were able to do single-digit and two-digit subtraction without carryover, but three of them made many mistakes in this task. One student wrote 2–2=2. Only two students were able to solve sums involving subtraction of three-digit numbers (without carryover). All the students were slow in all the tasks, except one student (Magnesium, more on him in section 3.2).

The intervention

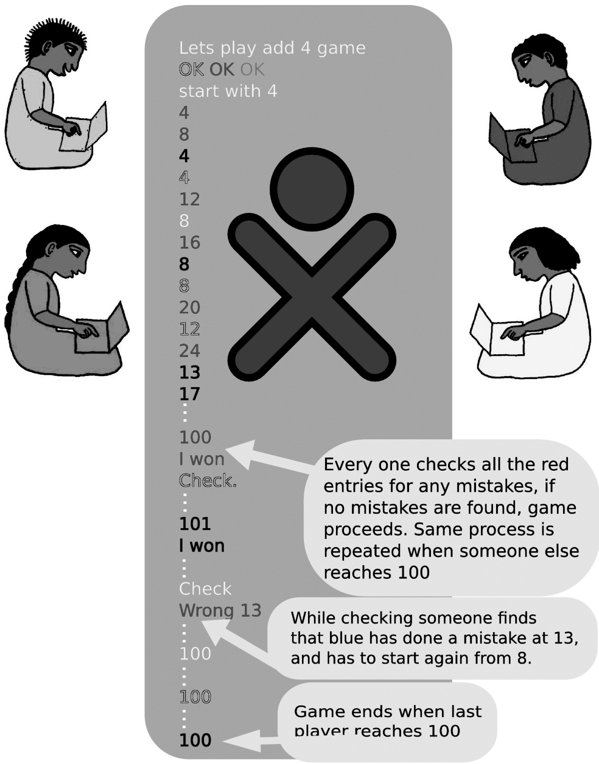

Figure 2. A schematic of a chat session

The interviews showed that students' writing and reading skills were good, but they had little numeracy skills. We wanted to improve their numeracy skills, and also support their literacy skills using the chat activity. Our first intervention involved playing a simple addition game, where a student (or teacher) first proposed a number (say 2), and then another number (say 3) that needed to be added to the first number cumulatively. All the chats happened in Marathi. In this example, the series proceeds in the following way (2, 5, 8, 11, 14, 17....) Each student creates this series by consecutive addition, until a three-digit number is reached. The first student who reaches the three-digit number wins the game (by declaring I WON; on screen, or aloud). The others then check all her entries to see if she made any mistakes. If she made a mistake, she has to start again from the correct element before the mistake. If she completed the series correctly, she goes out of the game, and the others keep playing, and the game continues until everyone reaches the three-digit number.

To start the chat application, someone starts a chat session and others join that session. As students join the chat, every computer screen shows who has joined. The screen shows the name of the joining person's machine, in the color of that machine (Every XO has a unique color, and everything done by that machine carries that color. This allows identifying different machines just by color.). When enough people join the session, the students decide, or the teacher decides, what game they want to play using chat. For instance, as shown in Figure 2, yellow (Y) suggests playing 'add 4' game. Blue (B), green (G) and red (R) agree. The next task is deciding which number should be used to start the game. Here again Y takes the lead and 'starts with 4'. Anyone can start with any one digit number. With this, the race starts. The objective of the game is to reach a three digit number, by repeatedly adding 4 to 4. Students do this addition in a very simple way in the beginning. They look at their last post, add 4 to it by doing mental addition (initially, they used hands to count) and post the answer. For the next addition, they look at this post and add 4 to it.

In Figure 2, R has posted 4, and then 8. B and G also started by writing 4. By the time B and G reaches 8, R has gone up to to 16. R is leading the race, followed by G, B and Y respectively. The game proceeds this way. In between, the students look at the screen, scroll using the mouse and see where they are in the race. The game stops for a moment when someone shouts or writes (when students are not in physical proximity) 'WON' or 'I WON'. In Figure 2, R says 'I WON'. Soon after, someone has to say 'CHECK'. Here G says it. Everyone checks all the entries made by R, by scrolling up using the mouse. They only look for entries in red color, and see whether she has done all additions correctly. If no mistakes are found, the game proceeds. R (the student who won) still participates in the game, but only when someone else says 'I WON'. Then R also participates in checking whether that student has made any mistake. The game again stops when B says 'I WON'. Y asks for checking, everyone starts checking all the entries in blue. Y finds that B has made a mistake at 13 – instead of 12 she wrote 13 – and all the entries following are wrong. The game resumes, and B has to start from 8 again. This process is repeated till the last person completes the game. In between the game, students find their mistakes, either by thinking about their screen entry, or by comparing it with entries made by others. They correct their own mistakes. To keep up with others, and to increase the speed at which they post their entries, students keep one hand over the ENTER key and the other hand on number keys.

Post-intervention test results

After five months of this intervention (3 hours a week), we did a personal interview similar to the pre-intervention interview (n=13). We found that the majority of students had remarkably improved their numeracy skills. Eleven students were able to identify and write numbers up to three digits when the numbers were randomly posed by the researchers. Before the intervention, most were able to only identify and write up to two digits. Their speed in identifying and writing numbers had also increased. Eleven students were also able to solve addition problems up to three digits without carryover. Similar improvement was seen in subtraction tasks. Ten students were able to solve subtraction problems up to three digits.

A preliminary analysis of the chat logs showed that 226 chat sessions were recorded, with the length of individual sessions varying from a few seconds to 20 minutes. Out of these sessions, 96 sessions were conducted when the researchers were present. The remaining 130 sessions happened during our absence. The children were initiating more chats on their own, and this is strong indication that they really liked the chat activity. Anecdotal evidence also supports this view. For instance, before starting the class, we used to ask the students "what should we do today?", and mostly the answer was "lets play chat activity". Also, the students used to be completely absorbed in playing the chat activity, and unlike the case of some other programs in the Sugar platform, we never had to force them to engage in the chat activity.

In the early period of intervention, students used to do simple additions using finger-based counting, which is easy, but takes time and works only for small numbers. After a while, these students started counting mentally. They also used their knowledge from school (multiplication tables), for solving addition problems (see section 3.2). These were significant shifts, possibly catalysed by the competition created by the chat game. To win, students needed to optimize their moves, and school knowledge was useful for such optimization.

The Distributed Cognition of Mathematics

Following Hutchins (1995), we will use a distributed cognition (DC) framework to analyse the role played by the chat activity in our classroom. This framework is suitable for two reasons. One, the chat application creates a socio-technical environment, and DC is currently the best framework to understand such environments. Second, the learning in our case happens through the transfer of representations, across many different modalities, and across a group of learners. Understanding this process requires taking the entire class as a unit of analysis, including the teacher, students and the laptops. DC provides a good framework for such an approach. Kirsh

(2010) also contributed to our understanding of how the structure of the chat activity helped the students and the teacher. In section 2.5 we have provided a procedural description of the tasks performed by the students in detail, particularly what kinds of representations are created, processed and transformed. In the next section, we examine the students' tasks from a cognitive standpoint. Due to space limitations, we do not discuss the teaching advantages provided by our chat game in this paper.

A cognitive description of the student's tasks

There are two kinds of cognitive processes going on in the chat activity. The first is the ones we can see directly, and are outside the individual students' head. Second is the ones we need to infer, involving processes taking place within individuals' heads. While playing the game, the students write a number and post it, creating a persistent external representation that is color-coded and indexed to an individual poster. This persistent representation helps learning in three ways. One, it allows a learner to notice and focus on her own mistakes and difficulties, as well as track her response time, in relation to others' mistakes and response times. Second, it makes it possible for others to contribute to the student's learning (Kirsh, 2010), by pointing out mistakes, and also setting up a peer environment, where the student knows that her mistakes are implicitly judged by others in relation to everyone's mistakes. Third, it sets up a turf for constructive competition, as well as a space for improvement, in terms of both accuracy and time.

To see the advantage provided by this system clearly, imagine a situation without the chat activity, where the game is played by calling out the number. In this case, the structure is not persistent, and therefore it is difficult to keep track of, both by the poster as well as her peers and the teacher. If the game is played by writing on a paper with pencil, it will not be immediately shareable with everyone. If the game is played using a blackboard, it will be immediately shareable but it wouldn't allow the competitive element to form, as the response speed will be affected.

Going to a more detailed level of learning, in the chat activity, the number is written on an external media that is persistent, and this allows the individual student to lower his use of memory space. The same posted number is used for the next addition. The student does not recall the number from her memory, she looks at her previous post and adds to it a number which she recalls from her memory. The number which is taken from the memory (here it is 4, as the game is to 'add 4') is used again and again, and the rehearsal process improves the speed of addition with that number. The complexity of addition also improves, as each instance of addition is with a larger number.

A second important learning event is the comparison between one's own posts and other students' posts, to decide where one is in the race, and/or to decide whether one did the correct addition or not. For this, a student looks at the entries surrounding her entry. The color of her own entry acts as an anchor and filter, and this reduces an enormous amount of cognitive load in processing her rank in relation to others.

A third important learning event is the 'CHECK', when someone says 'I WON'. When students are checking entries posted by that student, the task is a peer evaluation. But this evaluation is easy in the chat situation, as it involves looking for visual similarities (all the entries in that particular color). This checking is very engaged, as every one checks the posts on their own screens, and sees the posts in relation to both timing and accuracy of other posts, and the evaluation is quite deep. An individual learner's understanding of a mistake is thus clearer than possible with verbal, paper-pencil or blackboard versions of the game.

In the above description, the learning processes exploit external representations, which reduces cognitive cost. But there are certain processes in the chat game that do not migrate outside the head, because they cannot be executed outside in this game. One such process is mental addition. This process is important in our case, as we want students to learn to do addition quickly in their head (and say, not on a calculator on screen). The chat activity lowers the cognitive load on each individual in the group, but it focuses the cognitive resources of the group, making them available for learning the mental addition task individually, as well as while acting as a group in helping others learn addition.

Along with addition, other processes also run inside the head, such as: 1) deciding what strategy to be used for the addition task, 2) trying to adopt a new strategy from information collected from looking at others' posts, or 3) trying to find a new strategy. These are precisely the higher-level learning-to-learn aspects that we want to teach students. These higher-level features cannot be triggered by designs without chat, as they do not have the dynamic social and competition contexts that lead to strategy-level thinking. They focus only on addition.

The chat activity thus keeps cognitive resources available for what we want to teach students, and offloads or distributes most of the other peripheral things to the world, outside the individual's head. The activity also creates a social learning situation where the learner automatically moves to a strategy-level of learning. Apart from learning how to add, the activity provides a very rich context, where the children are not only able to focus on their own inscriptions, but also track others' performance. They are able to perform not only self-assessment, but also assess others' performance. Such learning, where students learn to assess others' mathematical ability, and rank their own performance in relation to others' at a detailed level, is not possible with current ways of teaching mathematics.

It is worth noting here that the students learned to read and write better while playing the game. In order to play and win the game, they had to read and write on the screen, that too at a very high speed. While this is a constraint that comes with the media and the externalization process, this constraint also led to students improving their reading and writing skills.

Magnesium: The effects of the social environment

The chat activity is happening in a social environment. The students are interacting with each other, and also with the teacher, while they were playing game. We believe this social environment provides the context for students to improve their mathematical skills, and then discover better strategies for solving problems, so that they can win the game. The same environment also allows them to learn strategies from others. We will illustrate these two points using a significant event that occurred during our study.

The first event is a discovery of a strategy by a student, and the propagation of this strategy through the class. While playing a special version of the addition game, where one number was proposed and the same number was added to it to get the series, we observed that one student (named Magnesium) left others far behind in the race. The change was so sharp that it was immediately noticed. This happened for the next few games as well, But after that, another student named Sulphur caught up with him. Now these two students left the others far behind. Everyone noticed this change. After a few games, many of them were doing additions at a similar speed. We tried to understand what was happening, and asked the students how they were doing the additions so quickly. Magnesium and Sulphur answered that *they were using multiplication tables* (which the students memorize in class) for the repeated addition, and this was the reason for the sudden decrease in response time. This strategy works only when the number to be added and the starting number are the same. For this reason, in the last few games, they were also purposefully keeping the two numbers the same.

Note that this shift is a radical one, given that many of the students started off by doing addition with their fingers. Now, not only can they do the calculation in their head using multiplication tables, they have also learned the connection between addition and multiplication in a deep way, such that they tweak the entire game structure in their favour.

This example clearly shows that students are actively looking for better strategies for optimizing their game performance. In the process, they are discovering patterns and inventing strategies based on what they learn in the classroom. These strategies then propagate through the class. This is possible because of the shareable and persistent nature of the external representations created by the chat activity. When students continuously interact with the external representations, new patterns emerge, which leads to discovery of new strategies. Sharing the strategy using external representations makes its propagation possible (Kirsh, 2010). We have seen similar patterns when students switched from counting with fingers to sequential addition (also see Fuson et al, 1997).

We believe that this discovery and propagation of a new strategy occurred also because of the social environment of the chat activity. Children like competition, and the ‘6 seconds fame’ they get when they win the game. This motivates them to learn or find ways with which they can do the activity faster, and reach the goal before others. Even when someone reaches the goal very late, we have seen them showing similar joy as the winning students. Also, though they want to compete, they were seen cooperating as well. The student who finishes first returns to one of the playing students, and begins to support him to reach the goal. The chat activity thus provides the context for the social learning of mathematics.

Future Work

Data collection in this study is completed, and we are in the process of analysing the chat logs. We expect many important patterns to emerge from the logs, particularly the actual improvement in speed and accuracy over time, and how this pattern spread over the sample. Also, we will look at the multiplication case in more detail, to see how the optimization technique spread through the population. We expect to discover other such cases from the log analysis. These analyses would be able to provide insight into how new strategies are discovered/learned and how they propagate through an entire class. Also, how performance in the activity is related to motivation. These details would help us in designing new activities, particularly a similar chat application we are designing to teach the concept of area.

Conclusion

In this paper, we reported our experience using the chat activity as a social constructionist medium to teach numeracy and arithmetic skills. Our task was designed as a game to motivate students to learn numeracy skills as well as literacy skills. The students learned to use multiplication tables as an optimisation strategy. This experience provides some pointers on ways to design games inspired from close-to-life social context, for not only mathematics but other subjects as well. The study shows that the externalisation of representations can not only offload memory, but also lead to a closer focus on the essential task at hand. The design of the game also provided a quicker feedback to the students by providing them with a self as well as peer-to-peer assessment model. This initial study opens up several exciting possibilities to use a simple simulated game-like social environment for an effective and motivating means of teaching, learning and assessment.

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