



# Mate Marote: A flexible automated framework for large-scale educational interventions



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## ABSTRACT

There is big consensus that computer games may be an effective way of learning and many initiatives are being developed where aspects from cognitive sciences are being applied in the development of these games. In this article, we present Mate Marote, a flexible framework for large-scale educational interventions. Based on the delivery programs of computers to each student in Argentinian schools, we developed an environment that provides activities/games and registers usage statistics. This framework keeps installation up-to-date connecting with a central server as Internet connection is detected, synchronizing new activities, version updates and usage history. As a first testbed intervention, we deployed three games in La Rioja province (Argentina), where OLPC is the official program. These games were focused on training inhibitory control, working memory and planning skills. We found that usage statistics of games replicate previous results found at the laboratory, showing that this platform works as an intervention framework despite its unsupervised nature.

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## 1. Introduction

Education is a fundamental piece of our culture which persistently influences every aspect of society. As the world moves deeper into information-based societies, the contrast between traditional educational approaches and the real-world challenges that students and graduates face is becoming starker. We present here an educational tool to help bridge this gap by incorporating information technology and scientific advances directly into the educational cycle.

We live in a digital era, where a significant fraction of students and teachers have their own laptops. Worldwide initiatives around the world are being implemented, delivering low-cost laptops to every primary and secondary school students. Many programs are adopting the One Laptop Per Child program (OLPC).<sup>1</sup> This is happening today in Uruguay with the OLPC CEIBAL program,<sup>2</sup> where the whole population of elementary schools – some 400,000 children and their teachers – are using the same digital platform, and in La Rioja province (Argentina), through the Joaquín V. González program.<sup>3</sup>

This new social phenomenon has the potential of making a profound change in the education of millions of children around the world. The fact that all learning and teaching tasks are represented in the same digital environment is a remarkable opportunity for educational

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<sup>1</sup> <http://www.laptop.org/>.

<sup>2</sup> <http://www.ceibal.edu.uy/>.

<sup>3</sup> <http://www.programajoaquin.org/>.

applications, as well as for research and interventions. This tool allows for real-time observation of the learning and teaching process while students and teachers interact in class or at home, to access different expressions of the students' thought processes, and to monitor the effect of different educational strategies at different ages.

Simultaneously, a new discipline has emerged not so long ago – called *educational neuroscience* – combining cognitive neuroscience and behavioral methods to investigate the development of mental representations and, possibly, to use neuroscience preexisting knowledge to improve different teaching approaches (Goldin, Calero, Peña, Ribeiro, & Sigman, 2013; Lipina & Sigman, 2012; Posner & Rothbart, 2007).

Traditional education in schools consists of supervised learning, where teachers communicate knowledge in classrooms and attend individual children questions. Generally, classrooms are populated by many students per teacher, and thus teachers have very little time slots with each individual child. For more than 20 years, Cognitive Tutors have supported individual students for guided learning, helping teachers that have very little time to spend with each individual child (Anderson, Corbett, Koedinger, & Pelletier, 1995). These tutors have shown comparable results to human tutoring (Aleven & Koedinger, 2002). This implementation relies on the installation of the corresponding software on each computer or a constant Internet connection. Thus, this solution results suitable for using the tutors in computer labs at schools or small-to-middle scale experiences (Koedinger, Anderson, Hadley & Mark, 1997).

In particular, several projects propose the introduction of games in the classroom as part of the education activities (Green & Bavelier, 2003; Liu & Chu, 2010; Rosas et al., 2003). Some authors propose competition-based game for stimulating learning (Burguillo, 2010); others suggest user-centered games for stimulating higher education (Ebner & Holzinger, 2007). In summary, many initiatives introduce different games as a strategy to stimulate learning in children. Mate Marote serves as a general framework for integrating these initiatives in a common platform, where activities and games are updated automatically and usage statistics are collected.

We present a general-purpose framework for massive-scale educational interventions, which integrates three main concepts: large-scale, educational interventions and gaming for learning. We focus on province or even country wide implementations in the Latin-American context, where permanent Internet connection cannot be assumed. Updates and Intervention activities – such as intelligent tutor systems, classroom work, games, etc. – may be added to the server and flooded into the client computers when broadband connection is detected.

We show a first case study, a province-wide intervention in La Rioja province (Argentina) which consists of three games that train basic cognitive abilities (inhibitory control, planning and working memory) in the first two grades of primary school. The training intervention is designed in a completely unsupervised manner to enable massive scaling at no cost.

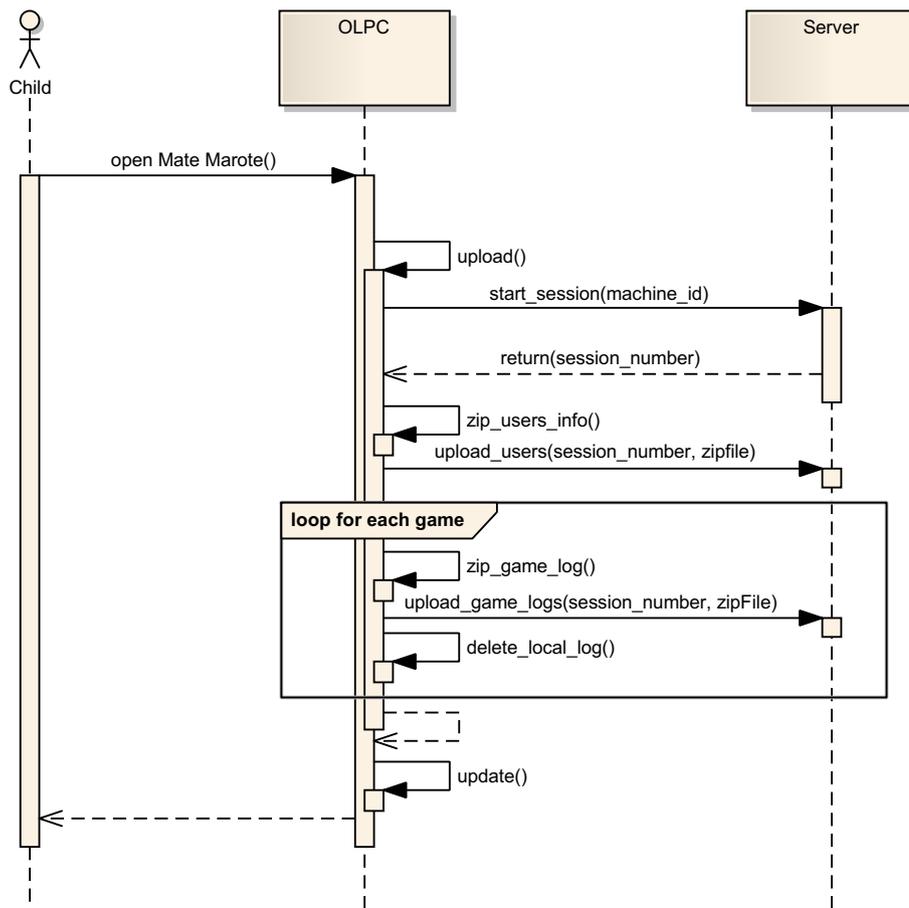


Fig. 1. Upload step. If connection is detected, the framework packs all statistics of games usage and uploads it to central server.

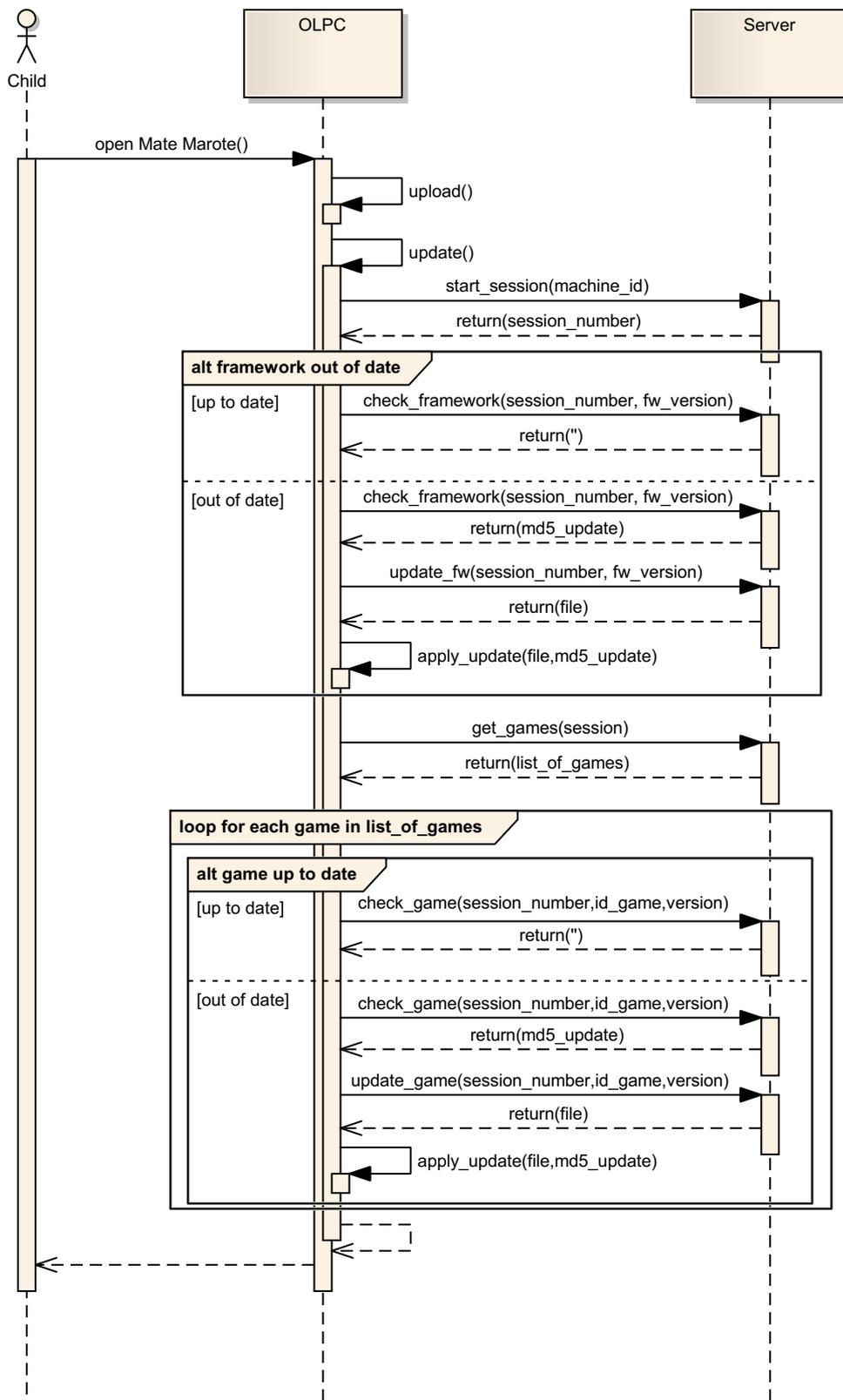


Fig. 2. Update step. After uploading statistics of usage, the framework connects to the server and checks for system and games updates.

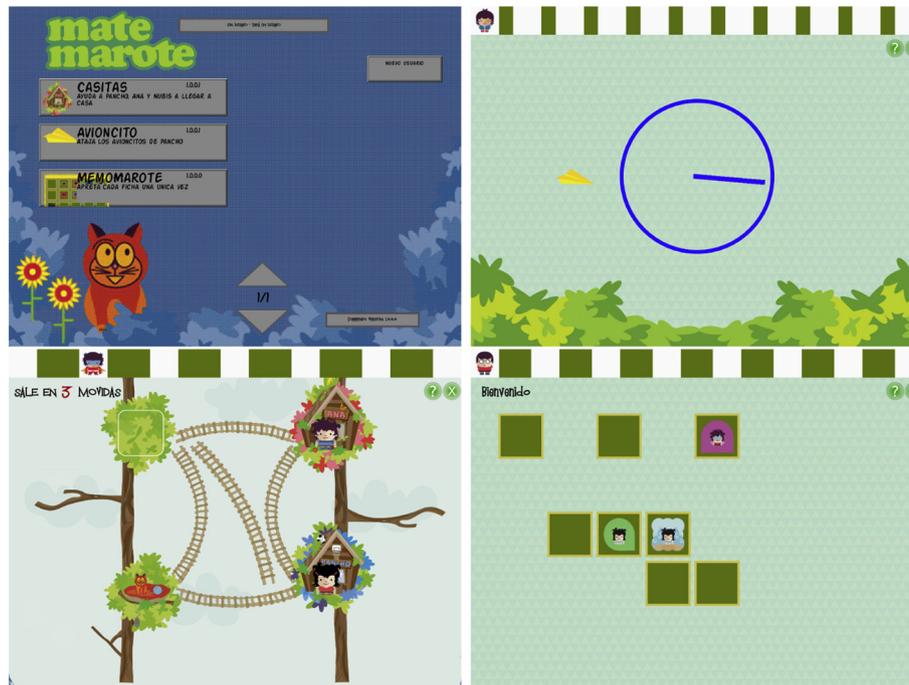


Fig. 3. Screenshots of main screen and games deployed in pilot intervention in La Rioja. 120 computers were manually installed with this first pilot intervention designed for testing the system. Top left: main screen; top right: Avioncito; bottom left: Casitas; bottom right: MemoMarote.

## 2. Mate Marote: design and implementation

### 2.1. Framework

We designed a free open-source software to provide a general framework for educational intervention activities. The main 1-to-1 programs in Argentina are Joaquín V. González (running on all primary schools in La Rioja) and ConectarIgualdad<sup>4</sup> (running on all secondary schools of the country). The former program delivers OLPC laptops, installed with Fedora Linux operating systems, and Sugar desktop. The latter, delivers computers similar to Intel Classmate, with dual boot: Windows and Linux. On the other hand, Uruguay has implemented a 1-to-1 program using the OLPC platform in all levels.

All these 1-to-1 projects in Latin America include the installation of connectivity infrastructure in schools and public places. However, these connections are not trustful. It cannot be assumed that every computer will be connected all the time, so a web-based implementation was discarded. Instead, we decided to implement Mate Marote as a local-running application, with a Central Server that provides updates of base system or games and receives statistic of games use when connection is detected. We decided to use Python language due to its portability, simplicity, easy-of-use, and readily availability of data structures.

The general infrastructure of Mate Marote is designed to manage multiple 1-to-1 programs, enabling specific customizations in each specific deployment. This feature is based on profile management, where each computer is assigned to a single profile. This profile consists on a list of customization of activities, games and configuration parameters, such as games difficulty. For instance, we could think of a profile for 1st and 2nd grades in La Rioja, and two different profiles for primary and secondary school students in Uruguay.

When Mate Marote is opened, if connection is detected the server provides updates of system and games and receives the statistic of games use. This process is split in two steps: *upload* (for statistics uploading) and *update* (for systems and games updating). Before starting any of these processes, a connection must be established where computer identifies itself through its MAC Address. If the computer is an XO, it also includes its serial number. This identification is used to check if the computer is already registered and select the corresponding profile.

The *upload* step (see Fig. 1) consists of –first– uploading local users to server and then uploading statistics of use.

For each game, a ZIP file is generated with statistics of use of the particular game and uploaded to server. After all games reports have been uploaded, updating is performed.

The *update* step (see Fig. 2) consists of comparing the current version of the framework (obtained from server) with the installed one. In case difference is detected, an update patch is automatically downloaded and installed. After base system has been verified and updated, each game is checked based on the server list. Then, for each game in list current versus installed versions are compared and in case of difference update patch is downloaded and applied.

We propose a framework for massive-scale interventions; therefore this framework must be designed for unattended installation and maintenance. One of the most common problem in network applications is firewall issues. To avoid conflicts with firewall configuration, all communications between computers and the server are done using the HTTPS protocol (on the standard port 443). This design decision ensures that, if computer has access to standard HTTPS protocol, it will be enabled to connect to the server. The server was implemented

<sup>4</sup> <http://www.conectarigualdad.gob.ar/>.

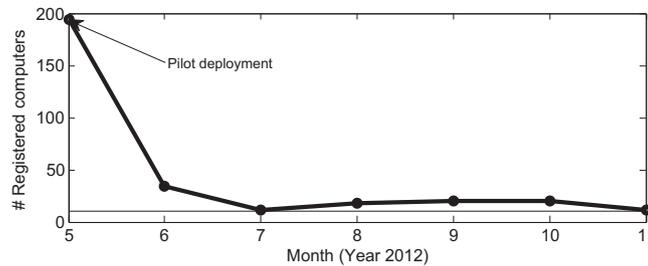


Fig. 4. Number of computers registered from May (pilot intervention) to November.

using CherryPy, a python-implemented web server, connected to a Postgresql database (see Supplemental material for a complete schema of database design).

## 2.2. Games

As a pilot intervention, we implemented a set of three games designed to train specific cognitive functions in first and second grade students based on well studied neurocognitive abilities: inhibitory control (Game 1: *Avioncito*), planning (Game 2: *Casitas*) and working memory (Game 3: *MemoMarote*).

Inhibitory control refers to a specific group of cognitive functions related to attention, voluntary and conscious actions and is of special relevance in situations which involve sustaining information in time, conflict resolution, inhibition, and on-line maintenance of information (Garon, Bryson & Smith, 2008; Posner & Rothbart, 2005). We developed a game (called *Avioncito*) consisting of a series of exercises which entrain inhibitory control and attention based on the stroop effect (MacLeod, 1991). In other words, the game trains the ability to inhibit a dominant response leading to a sub-dominant answer. By measuring response times and correctness of responses, education researchers may obtain some information about the development trajectory of the inhibitory control system during child development (Garon et al., 2008).

Adults and children differ substantially in their ability to solve problems. A source of this difference could be the availability of a repertoire of general-purpose procedures of problem solving in adults, called “weak methods” (Klahr, 1985). In the *Casitas* game, we test this hypothesis by the development of a planning game based on the Dog-Cat-Mouse game proposed by Klahr (1985). Then, we study which (and how) methods are used by children at different ages to understand the underlying mechanisms responsible for the development of the general-purpose procedures,

Working memory refers to the capacity to store and manipulate information for very brief periods of time (Baddeley & Hitch, 1974). This capacity is limited to a few items both in adults and children (Cowan, 2001). We train this ability by a game (called *MemoMarote*) based on a non-spatial, pattern recognition working memory task, a paradigm that measures recognition memory for visual patterns, but not spatial locations (Luciana & Nelson, 1998; Petrides & Milner, 1982).

## 3. Results

### 3.1. Usage monitoring

We developed a general framework for large-scale educational interventions. To test the system, we performed a pilot study in La Rioja province (Argentina). This intervention consisted in the deployment of three games for training specific cognitive functions in first and second grade students: inhibitory control, memory and planning (see previous section for a detailed explanation of games). In Fig. 3 we show screenshots of the main screen and one of each game to illustrate games design (note that the screenshots are in Spanish as the intervention is deployed IN Argentina).

These games were deployed manually in 120 computers belonging to 1st and 2nd grade students from three schools on May 15th, 2012. Each computer must be assigned to a unique profile – representing a particular intervention – when it is registered. Initially, as there is no other intervention active, we configured the server with the *pilot* profile as default one, so *pilot* profile is automatically assigned to any computer which connects to the server. When a computer connects for the first time, all database structures are initialized and the *pilot* profile is assigned. After that, the three games are served and installed.

On December – 7 months after pilot intervention – we analyzed the connection log of previous months to calculate the number of registered computers per month (Fig. 4).

We observe a peak in the number of registered computers in May, when the pilot deployment was performed. Interestingly, the number of registered computers during this month was almost twice than the ones we manually installed. We theorize that this surprising event is due to many facts: (1) teachers from rural zones assisted the training talks to install off-line the framework back in their schools; (2) our visit was published in the local newspaper and the Joaquín V. González program blog<sup>5</sup>; and (3) children may share the application to their classmates or friends by a single click thanks to the Sugar desktop<sup>6</sup> included in the OLPC program. The blog is read by many teachers from different schools regularly, and so they may spontaneously suggest the installation of the framework to their students. These additional registrations were also found during the following months. Note that every month there was, at least, 10 new registered computers (Fig. 4, thin solid line) showing a small viral effect where new computers are registered regularly.

<sup>5</sup> <http://programajvglarioja.blogspot.com.ar/>.

<sup>6</sup> <http://www.sugarlabs.org/>.

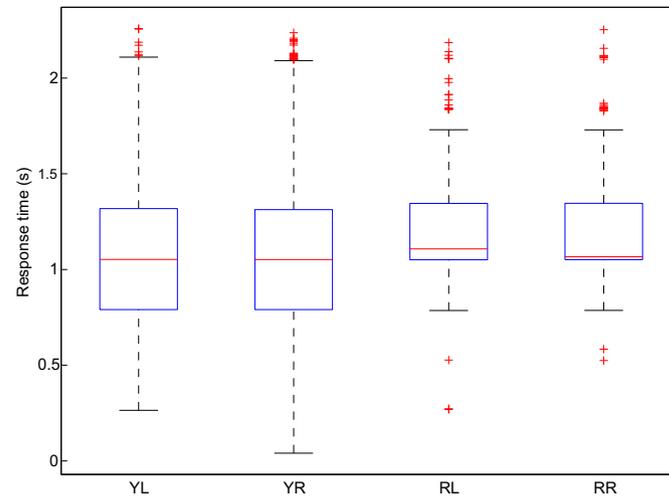


Fig. 5. Response time of players for the inhibitory control training game, split into Yellow and Red planes pointing Left (YL, RL) or Right (YR, RR). Red planes show a significant increase of approximately 100 ms in concordance to supervised experiments.

### 3.2. Behavioral analysis

Children may play the installed games in school (under teachers instructions), at home, with friends or at any other time. This scenario is radically different from controlled experiments where children visit a laboratory or researchers visit schools. In controlled scenarios, children are supervised while they *play* the experiment. In our pilot intervention, the use of games is performed in a completely unsupervised manner. We ask first whether this particular scenario shows the same behavior when children play the games in a supervised environment.

We compared the statistics of game usage based on previous results of the three games. To illustrate this result, we show the results of the inhibitory control game (*Avioncito*) as an example. In *Avioncito*, children have to select the direction of a plane. If the plane is yellow, player must choose the direction the plane is pointing at. Otherwise, if plane is red, player must choose the opposite direction. Typically, in the red scenarios players register a longer response time of answers and bigger error rates, indicating a higher complexity over the yellow scenario. This effect is widely known as stroop effect (MacLeod, 1991). In Fig. 5 we show the response times of correct answers, where YL refers to Yellow plane directing to the Left, YR: yellow-right, RL: red-left and RR: red-right.

We observe a small increase (approximately 100 ms) of response time in red planes ( $t$ -test,  $p < 0.01$ ), in line with other previous supervised results (Goldin et al., 2013).

This concordant behavior – i.e. results in supervised scenario similar to unsupervised conditions – was found for all the three games. We exposed only the inhibitory control game for clarity of reading.

## 4. Conclusions and discussion

Several world-wide initiatives have been developed to deliver low-cost laptops to school population. As a consequence, a significant fraction of children have their own laptops. A current challenge for computer, cognitive and education scientists is how to make best use of this technological resources to improve education.

Traditional education supports on supervised learning, typically commanded by teachers in classrooms. This approach constrains individual tutoring, as teachers have very little time slots with each child. Digital solutions – such as Cognitive tutors – have introduced digital-supervised tasks for guided learning, showing comparable results to human tutoring (Aleven & Koedinger, 2002). This implementation has shown promising results in small-to-middle scale experiences (Koedinger et al., 1997).

Recently, unsupervised solutions have proliferated. One of the best known initiatives is the Khan Academy.<sup>7</sup> This site consists of a library of over 3000 videos and associated exercises, interactive challenges and assessments. Some institutions are currently considering flipping the organization of classroom: viewing lectures at home and doing homework at school (Thompson, 2011).

Based on this new phase with massive-scale educational resources, several projects propose the introduction of games as part of the education activities for increasing motivation (Miller, 2009; Nicolaou, Korfiatis, Evagorou & Constantinou, 2009; Perry & Winne, 2006). We developed Mate Marote, a free flexible framework for large-scale educational interventions, an environment that provides activities/games and registers usage statistics. As a pilot intervention, we deployed three games focused on training inhibitory control, working memory and planning in La Rioja province, Argentina.

Compared to the majority of prior initiatives our work had two distinctive novelties which are very relevant for the potential up-scaling of such an initiative: 1) use of games was completely unsupervised and 2) diffusion and proliferation of the game happened in peer-to-peer interactions. A fundamental test to examine whether this initiative is feasible is whether the quality of play was comparable to an

<sup>7</sup> <https://www.khanacademy.org/>.

intervention with one-to-one supervision (Goldin et al., 2013). The results shown here indicate that data collected in an unsupervised design shows a very similar behavioral pattern.

Our analysis of statistics of usage and sharing indicated that students (and teachers) share the applications and do spread the games to other computers. The scale of growth was not sufficient for massive viralization given the number of seeds in this intervention. However, without any directed effort, diffusion, promotion, it shows already growth by peer-to-peer sharing. This encouraging result suggests that more massive proliferation in future installations is possible increasing the number of computers in which the software is installed and diffusion of the games to teachers and students.

The possibility of designing a nation wide educational experiment based on games presents unique opportunities for research in education and in cognitive psychology. Several projects have built on massive human computation to solve open problems. For instance, Games With A Purpose (Von Ahn & Dabbish, 2004; Von Ahn & Dabbish, 2008; Von Ahn, Liu & Blum, 2006) or predicting protein structures (Cooper et al., 2010). Through the analysis of stereotyped patterns of human thought, together with real-time observation of the learning and teaching process, we expect to allow the identification of subtle expressions of the students' thought processes and monitor the effects of different educational strategies.

This new framework opens up a new perspective on massive-scale interventions, with an inexpensive and scalable implementation for educational incursions. We showed a pilot intervention for first grades of primary school, training only three specific cognitive functions. We envision the development of new games to train other cognitive functions using this platform in the future, for instance, numeracy (Dehaene, 1997), meta-cognition (Schoenfeld, 1992), language (NICHD Early Child Care Research Network, 2005) and spatial reasoning (Newcombe & Frick, 2010).

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.compedu.2013.05.018>.

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