A collective brain to adapt teaching to quarantined first and second graders.

Roberto Araya [1],

[1] Center for Advanced Research in Education, Institute of Education, Universidad de Chile, Periodista José Carrasco Tapia Nº 75, Santiago, Chile
roberto.araya.schulz@gmail.com

Abstract. The education of first and second graders was the hardest hit by the pandemic. They have to learn to read, which is the biggest learning leap one can take. However, learning to read with a remote teacher is very complex at that age, and even more difficult in vulnerable sectors without access to computers or internet. In this work we investigate whether a playful smartphone based territorial ecosystem of collective brain among teachers of first and second graders can be implemented in the current pandemic and study to what extent it fosters the exchange and improvement of teaching strategies among teachers. Based on the experience gained on the ecosystem built in 2019, the system was adapted in order to encourage the sharing of teaching strategies between teachers. We obtained our data from the online territorial ecosystem where we received 450,000 responses from students, and from 3-minute videos made by teachers and shared on the ecosystem. We found that 640 teachers adopted the ecosystem App, with 98 of them sharing their strategies by uploading 3-minute videos. From these videos we also found evidence of an evolution of the strategies, which may have come from teachers imitating and improving on the strategies shown in previous videos.

Keywords: Territorial Ecosystems, Co-Design Strategies, Collective Brain, Social Innovation, Mobile Learning, Scalability

1 Introduction

COVID-19 caused a huge disruption to education in 2020. According to the UN Secretary General, "now we face a generational catastrophe that could waste untold human potential, undermine decades of progress, and exacerbate entrenched inequalities" [1]. The COVID-19 crisis cannot be reduced to a public health emergency as it has imperiled fundamental human rights including the right to education [2]. The pandemic is amplifying the global learning crisis and has disrupted learning for more than a billion students globally. It is estimated that the extended periods of school closures could increase the learning poverty rate to 63 percent, leading to significant negative effects on learning and human capital development [3].

1.1 Why are first and second graders the hardest hit?

The biggest educational problem caused by COVID-19 is in 1st and 2nd grade. There are several factors behind this.

First, the transition to primary education is a huge leap since first grade represents the start of formal learning. It is a far more ritualized and structured learning environment [4]. In first and second grade, children have to stop following their own educational interests and, for the first time, start attaining externally imposed, preset academic competencies, such as reading and mathematics.

Second, learning to read completely alters our brain. Neurologically, the brain is rewired, the corpus callosum thickens, the part of prefrontal cortex that is involved in language production is altered, and facial recognition processing shifts to the right hemisphere [5, 6]. Acquiring the ability to read is completely new in human evolution. This is one of the main features that defines the very particular psychology of Western Educated Industrialized Rich and Democratic (WEIRD) people [6].

Third, students at that age lack the self-regulation and autonomy needed to follow instructions, use online platforms and carry out activities independently. School and instructional processes can explain a remarkable amount of a student's development in self-regulated learning [7]. Schools foster self-regulated learning, so one year without schooling can have a huge effect on learning. This is especially challenging for students with poor self-regulation. They are the ones who benefit most from attending school. These students acquire the sorts of self-regulation skills at school that others acquire at home [8].

Teaching reading is even more challenging in developing countries. As of October 2019, 53 percent of children in low- and middle-income countries were unable to read and understand a simple text by age 10. An example of this difficulty is the level of illiteracy that still exists. Illiteracy costs the world economy more than USD 1 trillion annually in direct costs [9]. The last Programme for International Student Assessment PISA 2018 [10] study concluded that globally the percentage of 15-year-old students in grade 7 and above who reached a minimum level of proficiency in reading (at least Level 2 on the PISA scale) ranged from close to 90% in Beijing, Shanghai, Jiangsu and Zhejiang (China), Estonia, Macao (China) and Singapore, to less than 10% in Cambodia, Senegal and Zambia. In the US almost 40% of the elementary school day is devoted to the subjects of English, reading, and language arts, all of which contribute towards the development of literacy [11]. However, 33% of students in Grade 4 score below a basic level of proficiency in reading, as measured by National Assessment of Educational Proficiency (NAEP) tests [12].

1.2 What is the difficulty of teaching to read remotely?

The closure of schools in response to the COVID-19 pandemic has led to a 30% loss of classes in the US. According to predictions, this can translate to a loss of up to one year of learning. This loss is even greater among vulnerable families [13]. Another study looked at results from standardized tests in the last year of primary school at Flemish schools in Belgium to analyze the effects of school closures [14]. The study found that after just 3 months of lockdown and schooling via online platforms,

students from the 2020 cohort experienced significant learning losses in all tested subjects. This included a decrease in average school-level mathematics scores of 0.19 standard deviations and Dutch scores of 0.29 standard deviations when compared to the previous cohort. The inequality within schools rose by 17% for math and 20% for Dutch, and inequality between schools rose by 7% for math and 18% for Dutch.

One challenge when it comes to teaching first and second graders remotely is the critical dependency on parents. In normal, non-pandemic times, parents are already essential for improving student attainment and learning outcomes. In the primary years, family influences have a more powerful effect on a child's attainment and progress than school-level factors. At age 7, parent effects explain 29% of the variance in attainment, while school effects explain only 5% of the variance [15]. However, parents do not have effective strategies for supporting learning at home and such strategies are very difficult to discover or learn independently. This challenge is made even more difficult by the fact that there are two rival strategies for teach reading. This has led to a pedagogical dispute that has been going on for nearly a century, and which has been described as the "reading wars". While one of the strategies is effective according to empirical evidence, many teachers and parents use the wrong strategy or an inefficient mix of the two. Thus, in 1997, the U.S. Congress asked the National Institute of Child Health and Human Development (NICHD) to work with the US Department of Education to establish a National Reading Panel [16] that would evaluate existing research and evidence to find the best ways of teaching children to read. The National Reading Panel reviewed all available research (more than 100,000 reading studies) on how children learn to read and concluded that the best approach to reading instruction is one that incorporates explicit instruction in phonemic awareness, systematic phonics instruction, methods to improve fluency, and ways to enhance comprehension.

Another challenge is how to adapt these teaching strategies to an extremely heterogeneous range of home and family contexts. For example, not all homes have access to computers and the internet.

However, most homes do have mobile phones. Mobile technology has led to a positive impact on several areas, including a reduction in poverty [17]. Additionally, smartphones are now ubiquitous all over the world. A recent Gallup World Poll [18] shows that 83 percent of adults in developing economies have a mobile phone as of 2018. A recent 2019 World Bank Report [19] shows that people are increasingly using smartphones, tablets, and other portable electronic devices to work, organize their finances, secure and heat their homes, and have fun. Therefore, a smartphone-based strategy could, in principle, reach most homes.

If the confinement continues, the setback could lead to up to 2 years of lost learning. In this paper we describe a strategy implemented using the ConectaIdeas smartphone based territorial ecosystem adapted to address the interruption caused by school closures. This system uses strategies that help teachers to adapt quickly to this new context and facilitate learning at home, thus avoiding a significant loss of learning.

1.3 A collective brain is what we need

According to [20] our societies and social networks act as collective brains. One strategy for adapting to the challenge of teaching quarantined first and second graders is therefore to boost the collective brains of teachers and parents. In this paper we describe an adaptation of ConectaIdeas, a smartphone-based territorial ecosystem [21, 22, 23]. This system fosters collective learning, with teachers sharing strategies and what works in these highly unprecedented circumstances.

Humans are social animals with particularly powerful adaptations that help us learn from others. It is therefore important that we facilitate this type of learning. According to [24], individual intelligence is overrated and in the real world nobody operates in a vacuum. Instead, we work in teams and let the group do our thinking for us. There is growing empirical evidence on the power of learning in communities. For example, after studying different hunter-gatherer societies all over the world, Henrich [25] concluded that larger and more interconnected groups generate more tools, expanded bodies of know-how, and fancier techniques. If the community is very small, it can experience the "Tasmania effect". This is a regression that occurred in Tasmania. As the size of the community was reduced 12,000 years ago as a result of rising sea levels that cut them off from Australia, the aborigines were losing their know-how to make tools, weapons, clothing and boats, and going back to more primitive cultural tools.

Humans are cultural animals, animals that have evolved through natural selection to participate in a community, where the members not only relate to each other as individuals but are also shaped by their social network [26]. Our societies and social networks act as collective brains [20], where individuals selectively transmit and learn ideas that can produce complex solutions without the need for a designer. We therefore explore the effect on parents of using technology to connect them and teachers in a collaborative learning community that works to improve the children's learning.

Given the centrality of collective brains in cultural evolution, in this paper our research question is whether a territorial ecosystem of collective brain among teachers can be rapidly implemented during the pandemic. And if so, we are interested in knowing to what extent teachers innovate, share and recombine strategies through the territorial ecosystem, and if we can detect a process of evolution of teaching strategies.

The outline of the paper is as follows. In section 2 we present the collective brain framework, its evolutionary mechanism and its main components. Then, in section 3, we present the methodological approach that allows us to detect and measure the evolutionary process of transformation of teaching strategies in pandemic. In section 4 we present the implementation during 2020. Next, in section 5 we show the results, and finally in section 6 we present the conclusions.

2. How to implement collective brains?

In this section we present the conceptual framework of the collective brain adapted to the exchange of new teaching strategies to face literacy education in the COVID19

pandemic. We describe its main components: imitation, the evolutionary mechanism operating through several generations of strategies, and the territorial component.

2.1 Imitation is not enough

One critical mechanism for learning is imitation. This mechanism is widely present throughout the animal kingdom and is an essential force for animal and human societies [27]. Imitation is a key component of cultural transmission. It is favored in relatively stable environments, when the error rate associated with it is lower than the error rate associated with individual learning. This disposition towards comprehensive copying likely provides humans with a powerful mechanism for extracting maximal information from the social environment [28]. A learning ecosystem should therefore help parents and teachers imitate strategies that have already been implemented by other teachers. Cumulative cultural evolution is unique to the human species [29] but needs more than just imitation.

Copying fidelity is important if strategies are to be preserved [30]. However, once teachers start imitating their peers' strategies and ideas and parents start imitating the teachers' strategies, then we have to consider that the copies are not identical to the originals. Mutations invariably occur and therefore new strategies naturally begin to appear. Nevertheless, imitation with mutation does not lead to cumulative cultural evolution either.

The process of recombination is also key. As Ridley [R31] describes it, ideas start having sex with each other. This is the engine of human progress: the mating of ideas to make new ideas [31]. It is therefore critical that a learning ecosystem promotes and fosters the sharing and exchanging of didactic strategies, games and tools. This is the basic mechanism for social innovation.

The whole process is a typical evolutionary mechanism, but it needs to start from an initial population of strategies [32]. This initial set of strategies and ideas will jumpstart an iterative process. The learning ecosystem must therefore also provide an initial set of strategies. The population of strategies in each iteration is called a generation. In each generation, the fitness of every strategy needs to be somehow evaluated. This is a critical step to ensure the emergence of more effective strategies. These are strategies that are both highly motivating to young children and at the same time effectively help their learning. This means teachers need to have feedback on the strategies. In this sense, a learning ecosystem must also provide clear metrics that help teachers assess the effect of their strategies.

2.2 First generation of strategies to jumpstart the evolutionary mechanism

What are the initial ideas provided by the learning ecosystem? The system provides three types of strategies. The first strategy proposed is play. This is suggested together with different didactic games. This is considered one of the key tools to be imitated at home. It is very powerful since play is an ecologically-valid educational strategy used by mammals and several other animals [33]. Mother-offspring play among humans and non-human primates is widespread and central to offspring development. Indeed, such play has structural similarities across these species, such as exaggerated

movements and self-handicapped (slower and weaker) behavior of adults to facilitate offspring learning. Play is proposed through games, such as using dice with letters to challenge the child to form words and, eventually, sentences. Other games involve using whistles to help separate the different sounds in a word.

A second strategy proposed is the use of glove puppets or imaginary companions. Children are frequently exposed to anthropomorphic books, TV shows, and narratives. They are used to playing with non-living objects, such as hand puppets and stuffed toys, and perceive them to be agents that are worthy of social interaction [34]. Imaginary friends are used by 67% of children [35]. Several studies suggest [35] that having an imaginary friend confers a developmental advantage in a number of important socio-cognitive areas. Children with imaginary friends produced a range of more complex sentence types in a narrative task than children in a control group [36]. They produced significantly more adverbial clauses, relative clauses, and compound sentences, where clauses were connected using “and” or “but”. Using glove puppets as a tool for learning at home is therefore a reasonable strategy. If it is their own favorite glove puppet then the effect can be increased, since young children are less likely to accept an identical replacement for an attachment object than for a favorite toy [37]. This may be due to the fact that children believe that their favorite toy or puppet has a hidden and invisible property that distinguishes it from everything else.

Play and glove puppets can facilitate the development of powerful cognitive strategies in children, such as role-reversal imitation and transmission chains, in which children learn something and then teach another child [38]. However, in this case the child reads aloud to the puppet or has the glove puppet read aloud to them. This in turn facilitates the internalization process, where a child not only follows instructions but also self regulates their own problem-solving activities and instructs themselves.

A third strategy that was proposed involved having the children answer exit tickets on their own, with the parents sending them to the teacher. These are quick questions at the end of each lesson (Figure 1). This strategy was very important to implement remote work. They turned out to be the videos with the most views. Several alternatives for sending tickets were shown even without internet, and also strategies to receive and register them by the teachers.

2.3 The territorial component

In-group favoritism and ethnocentrism are human universals [39]. Humans are innately tribal. Experiments with children, adults and even monkeys with reaction time tests reveal negative associations with out-group members. However, markers can be created flexibly, extending beyond language, ethnicity or even race [40]. This powerful social force has been recognized in different ways since ancient times. For example, a related concept is cohesion, asabiyyah [41], or social solidarity. They emphasize group consciousness and a sense of shared purpose. One powerful group marker is territory. Capello [42] highlights that territorial identity is rooted in similarity and solidarity, which form the basis of identity. Therefore, a powerful learning ecosystem should include territorial facilities that use the in-group mechanism that fosters sharing and collaboration between parents from the same district.

3 Methods

To answer the research question of whether it is possible to implement a collective brain strategy through a territorial ecosystem we first describe how it was started, implemented, and the degree of adoption by the teaching community. Among some parameters that we propose to measure is the number of teachers that used the territorial ecosystem, the evolution of the number of teachers who uploaded tickets, the number of questions answered by the students, the degree of coverage of the curriculum in reading and writing and mathematics, and their respective learning objectives, the number of teachers who made 3-minute videos and upload them to the platform and share them with the teaching community.

Then to answer the second part of the research question we propose first to review the videos and define useful features present on the videos. The list of features is the following:

The video shows the ConectaIdeas Express App

The video talks about ConectaIdeas Express and its benefits

The video shows a video that is very different from the others

The video shows the students' answers to the tickets

The video shows hand-written student responses in order to assess writing

The video shows concrete teaching materials

The video shows practical strategies that are easy to reproduce

The video shows activities completed by their students

The video shows videos they have produced to send to their students

The video is considered very original by a panel of expert teachers

The video shows a teaching strategy that differs from traditional strategies

The video talks about the ConectaIdeas reports on student achievement

The video shows students answering tickets

The video shows a computer where the teacher receives the tickets

The video shows an educational game

The video shows a teddy bear or hand puppet

The video Shows a story book and reading a story aloud

The video explicitly states that the idea came from one of the videos in generation 1

The video explicitly states that the idea came from one of the videos sent by another teacher

The video shows a member of the school's academic team

The video shows the teacher visiting their students' homes

The video shows the school's principal

Next, to estimate whether the strategies evolved during the year, we define five generations of videos. The first generation are the videos made by our research team. These videos jumpstarted the evolutionary process. The second generation is the first quarter of the videos made by the teachers, the third generation is the second quarter of the videos made by the teachers, and so on.

To find out if there are changes in the features of the video populations between generations, we compare the percentages of features present in the different generations. In particular we are interested in comparing the second generation with the fifth generation.

4 Implementation

4.1 Innovation diffusion during the pandemic

Getting this evolutionary mechanism of strategy diffusion and innovation into operation in the midst of the pandemic is a significant challenge. On the one hand, it requires isolated teachers working from their homes to incorporate the territorial ecosystem into their practice. On the one hand, this involves downloading the ConectaIdeas Express App and connecting to the web through ConectaIdeas in order to monitor the progress of the class and the individual students. However, in a pandemic, it also requires recruiting quarantined parents and encouraging them to actively participate. Clearly, a digital transformation of this nature and in this particular condition is a disruptive transformation for both teachers and parents. Given the disruptive nature of the innovation, the proposed strategy was to use a proven conceptual framework to achieve adoption of the system and innovation of the didactic strategies. In this project we used the framework taken from Moore's Crossing the Chasm [43].

According to the Crossing the Chasm adoption theory, a disruptive new product or service is a significant discontinuity. It is not just about a new candy, a new model of car or TV. For really new and disruptive innovations the typical way in which the new product is assimilated or adopted by the population is well documented. For successful innovations (which finally reach the whole world), the adoption pattern is a very particular Gaussian curve where there is an abyss or chasm, which separates the adoption curve into two parts. Or, from the point of view of the cumulative number of users, from a certain moment the curve flattens out and does not continue to grow. This chasm does not exist for new products that are not disruptive. In this adoption curve, a great chasm is distinguished in the first part of the curve. What is critical is that the nature of the population before the chasm is totally different from the population to the right of the chasm, and therefore the strategies of broadcast (and also production, support and development) must be different. The presence of this chasm is the main difference between product adoption curves for traditional products and truly innovative and disruptive high-tech innovations that produce discontinuities in people's behavior.

Given this challenge of introducing disruptive change in the midst of the pandemic, the proposed strategy was to first identify, recruit and support groups of early adopters. This involved recruiting both enthusiastic teachers and visionary principals

from the school community, as defined by Moore's Chasm adoption theory. This means monitoring usage week by week in terms of the number of tickets sent, the number of student answers received and curriculum coverage. With this information, we were able to identify new early adopters every week, i.e. teachers and principals who were showing a more intensive use of the territorial ecosystem. These early adopters were given feedback via email and video, highlighting their achievements and giving them suggestions for increasing the value of the system and the intensity of its use. Moreover, we asked each of them to produce a 3-minute video showing their teaching strategies and how to reach families and students remotely. Approximately one quarter of these early adopters produced and submitted the requested videos.

While this segment of the population was being recruited to produce and upload their videos, a parallel strategy was implemented to recruit other members of the school community. As Crossing the Chasm suggests, on the other side of the chasm, the innovation must be more global and comprehensive; there must be much more training, support and guidance. Additionally, the recommended message for this section of the population has to be mainly social and referential. This means communicating that there are others who are already using the system intensively, as shown by a series of maps with key performance indicators. Here, references are particularly important. The best references are other teachers sharing their stories of using the territorial ecosystem. Even better are local teachers that belong to the same region. These teachers play the role of local ambassadors. The videos from the early adopters were therefore distributed weekly by email, together with links to the map showing the performance of the corresponding school and district. The strategy also included webinars to leverage the potential of gamification and promote the use of the territorial maps, showing key performance indicators of cumulative number of tickets as well as balanced coverage of the LO of the curriculum by school, district, and region.

4.2 The smartphone-based territorial ecosystem

A major challenge in education is how to improve teaching. One possible strategy is the use of Performance Support Systems [44, 45, 46]. These kinds of system provide real time support to their users, similar to how Waze or Google Maps help drivers reach their destination. In this paper we present the implementation of the ConectaIdeas Express app, which was added to the ConectaIdeas online teaching platform. This is a Learning Managing Platform hosted in the cloud that has been proven to be effective for teaching mathematics to fourth grade students in a RCT [47, 48]. The app was designed to help teachers carry out assessment in the classroom by using a series of quick questions, called exit tickets [49] (Figure 1). These are formative assessments that give teachers a way to quickly understand how well their students comprehend the material they are learning.

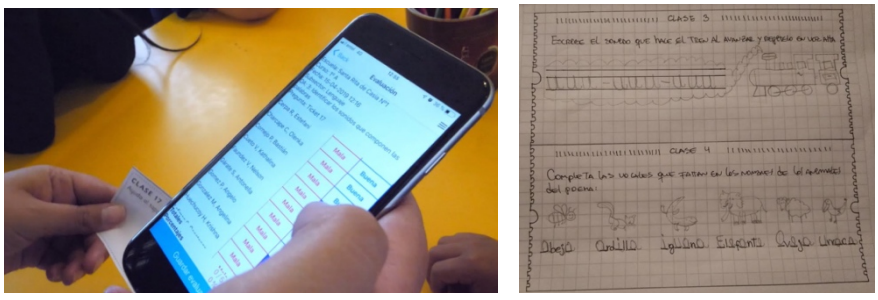

Fig 1. Left: the ConectaIdeas Express app used by teachers to assess student learning on different activities, all linked to official curriculum Learning Objectives. Right: two tickets answered by a student. In some of the tickets the students have to write, draw, or paint.

The app also allows teachers to constantly monitor each student's learning, as well as providing a concept map with the curriculum coverage. In this sense it shows a tree with the coverage of the official curriculum Strands and Learning objectives, as well as the average student performance on each (Figure 2). It also has a geographic information system that provides a social network for the parents and the rest of the school community within each district and region. While the teachers manage the app, parents can access the maps and information on a class-level (i.e. not on individual students) using their smartphones.

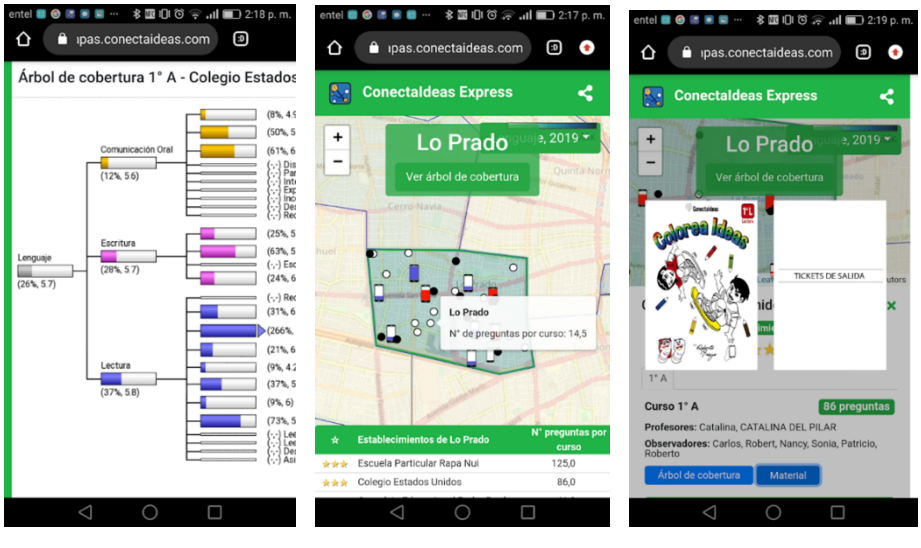

Fig 2. Left: a concept map tree showing each of the three strands with its coverage and performance, and each of the Leaning Objectives with its corresponding coverage and performance. Center: ConectaIdeas Express map with the schools of the Lo Prado district, and with a small smartphone showing the level of use of the app at each school. Parent activity is also shown on this map. This is part of the gamification strategy. Right: material that each parent and child can access by clicking on their school on the map.

The ConectaIdeas Express App allows teachers to use exit tickets without necessarily having to have an internet connection at the time of the assessment. Teachers can save the information on their smartphone and upload it later on, when they have internet access.

Given that the students were working from home, their parents sent the tickets by email or WhatsApp each week, or took the tickets to school twice a month when they went to pick up the food parcels that the government provided for each student during the pandemic. In some cases, the teacher visited homes to collect the tickets. Later, each teacher input the information into their smartphone. The tickets were designed by the Ministry of Education and shown in the official textbook. Each ticket is associated with a specific Learning Objective (LO) on the national curriculum. The program was addressed to schools that have a population of low SES students from all over the country. All training was done during the year via a weekly email with tips on how to install and use the app, as well as links to one-minute videos.

The territorial learning ecosystem was implemented as a geographic information system, with maps showing the level of activity by region, district and classroom. All the information on every class was shown in the territorial learning ecosystem for the whole country (Figure 3), with statistics on curriculum coverage per region. At the country level, an interactive map shows the average number of questions answered per class in each region of the country. These indicators are part of a gamification strategy involving teachers and families, and also district superintendents. Every week emails to the teachers and superintendents reminded them of their respective performance and curriculum coverage.

Each parent can access the map and zoom into any region (Figure 4). In each region, different districts are shown with their own activity indicators. Darker zones correspond to districts where more tickets have been completed per class.

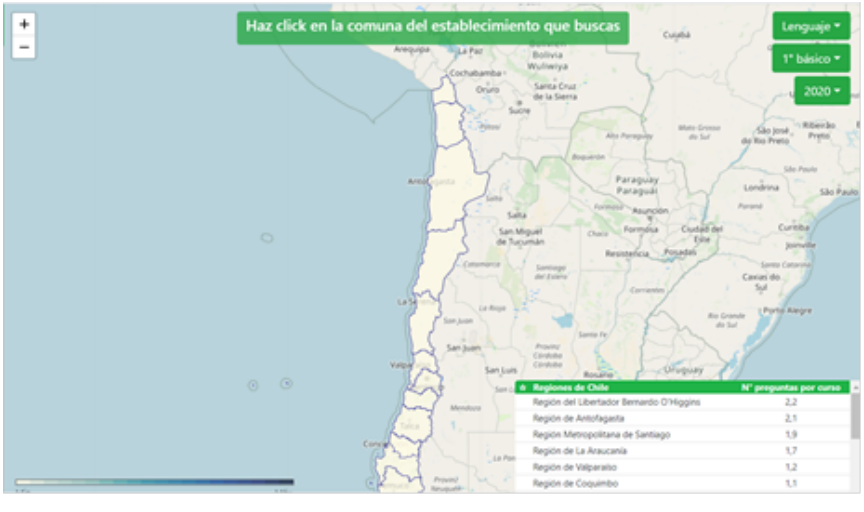

Fig. 3. Screenshot with the map of the country showing the average number of questions answered per class in each region of the country for 2020 in first grade in Language Arts (shown in the top right). In the bottom right is the list of regions with the average number of questions answered by each class. This map is part of the gamification strategy.

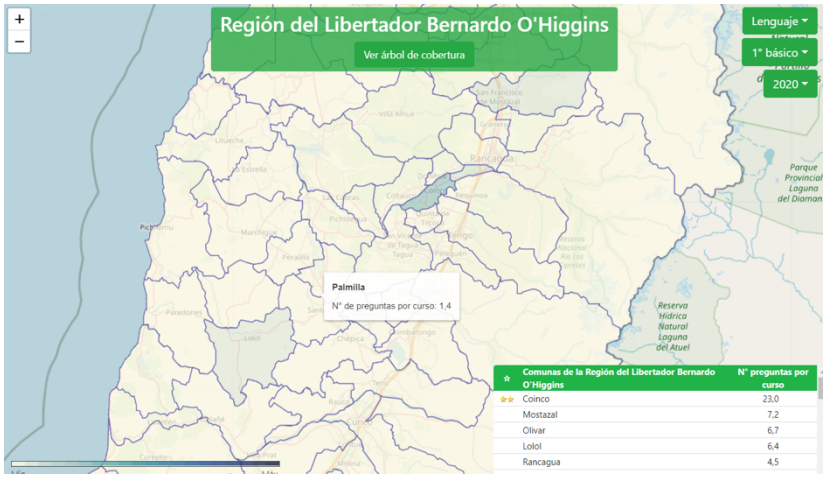

Fig. 4. Screenshot with map of the Bernardo O´Higgins Region showing the average number of questions answered per class in each district of the region. Darker districts mean a higher number of questions per class. In the bottom right is the list of districts in this region with the average number of questions answered by each class. This local map with the performance of the districts is part of the gamification strategy aimed at superintendents.

Any parent can zoom into a district and see all of the schools and classes in that district. Black dots are schools without first grade (Figure 5). White dots are schools not in the Ministry program. The cell phone icons are schools using ConectaIdeas Express. Red cell phones are classes where the teachers have produced a video and uploaded it to the system.

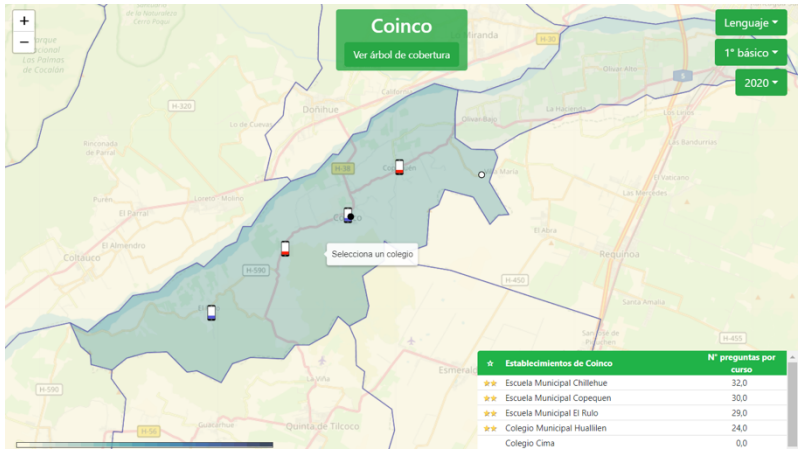

Fig. 5. Screenshot with a map of the Coinco district in the Bernardo O´Higgins Region showing the average number of questions answered per class at each of the schools in the district. To the right is the list of schools in the district with the average number of questions answered by each class. This local map with the performance of the districts is part of the gamification strategy aimed at principals.

If the user clicks on the smartphone the information on the class is displayed, along with the number of tickets and curriculum coverage (Figure 6). Moreover, if the smartphone is red it means that there is a parent-made video that has been uploaded for at least one class at that school. In this case, the video is shown to the left of the screen (Figure 4).

Fig. 6. Screenshot with parent-made video displayed to the left of the screen after clicking on one of the red smartphones on the map. Information on individual students is never displayed. This local map with the performance of the districts is part of the gamification strategy aimed at teachers and families.

Families, teachers, principals and superintendents can access all of the maps from their smartphones and share them through WhatsApp. While the territorial learning ecosystem can also be accessed via the web, parents tend to prefer the mobile version.

5 Results

During the 2020 school year, from mid-April to mid-December, a total of 640 teachers from low Socioeconomic Status (SES) Chilean schools voluntarily adopted ConectaIdeas Express, a smartphone-based support system, in order to help teach first and second graders how to read and do math [49, 22, 23]. On average, each teacher used the app and uploaded 48 tickets. This means that it was used approximately twice a week. Almost 300,000 student responses were uploaded for Language Arts (reading and writing) and 150,000 student responses for Mathematics.

All teachers received an initial version of the app, with the first generation of videos. This included two videos with strategies on how to deal with students and parents during the pandemic, as well as videos explaining certain teaching strategies (Section 2.2). These videos received more than 20,000 views. After the third month of implementation we contacted the teachers with largest number of tickets uploaded via email and asked them to contribute with a video. As a result, ninety-eight teachers from across the country produced and uploaded a 3-minute video to the territorial ecosystem. These represented the second generation of videos.

We analyze two types of results. First, we analyze the adoption curve. The question is whether we can get to the chasm and cross it. Second, we analyze whether the teaching strategies evolved over the course of the school year and look at the kind of changes that occurred.

No flattening of the adoption curve can be observed (Figure 7). The growth even continues over the last 4 weeks, when the school year is coming to an end. On the other hand, when compared to the previous year, the growth was slower. However, the difficulty of adopting a new system during the pandemic is much greater given the lack of internet connection in vulnerable sectors. Indeed, all school activity was considerably reduced in these sectors.

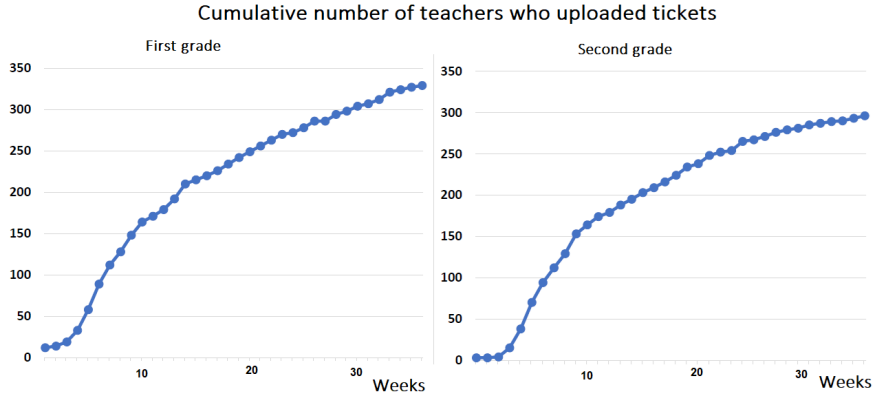

Fig. 7. Cumulative number of teachers who uploaded tickets. Left: first grade. Right: second grade.

More student responses were received in Language Arts than in Mathematics (Figure 8). These are tickets received by the same teachers with answer of the same students. The only difference was the subject matter. Both adoption curves increase constantly. However, the rate is higher in Language Arts.

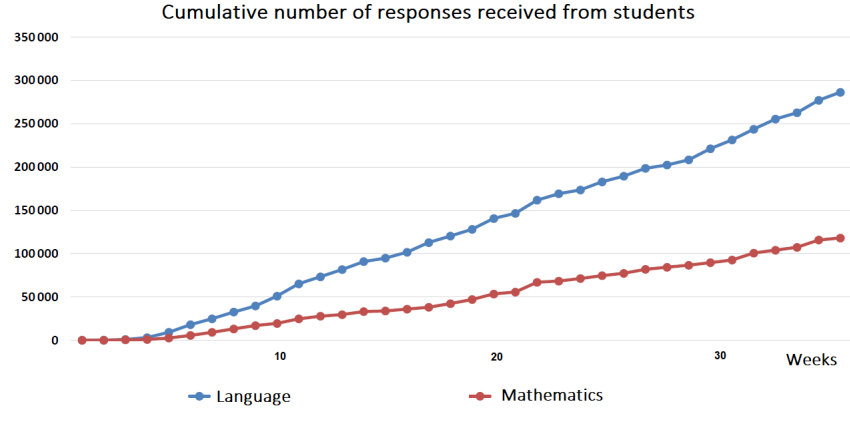

Fig. 8. Cumulative number of answers received from students.

No tickets were answered for the Oral Communication strand (Figure 9). This is to be expected as it is very difficult to evaluate the Oral Communication Learning Objectives without direct face-to-face contact or over the internet with video. On the other hand, there is a clear difference between first and second grade. In second grade, the teachers received as many responses for Reading as for Writing, while in first grade most were for Reading.

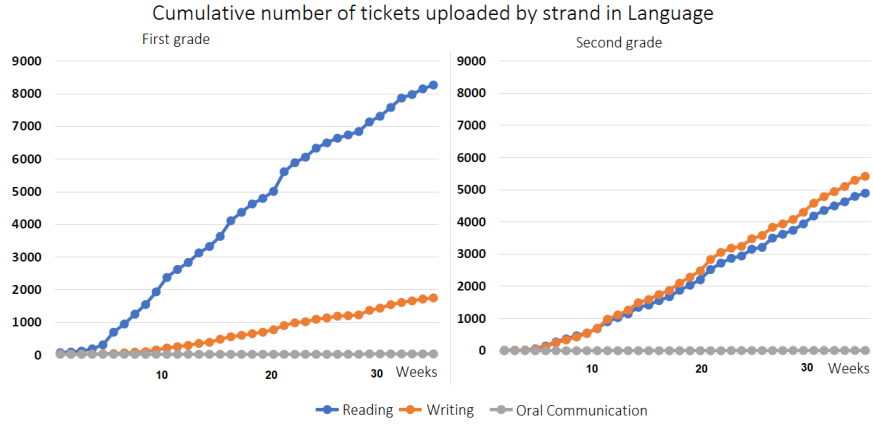

Fig. 9. Cumulative number of uploaded tickets on the three strands of the Language Arts curriculum. Left: first grade. Right: second grade.

We now present the results of the videos uploaded by the teachers to the territorial ecosystem, with 78% of them coming from urban schools. All the videos lasted between 2:50 to 3:00 minutes. If they were longer, a member of the research team asked the teacher to select the most important scenes in order to reduce it to 3:00 minutes. Most of the videos showed the ConectaIdeas Express app and how they used it (Table 1). All of the teachers recommended the app and gave tips on how to use it to track student achievement for the main Learning Goals on the curriculum.

As mentioned in the Methods section, to see if the strategies evolved during the year, we define five generations of videos. The first generation are the videos made by our team. These videos jumpstarted the evolutionary process. The second generation was the first quarter of the videos made by the teachers, and so on. Thus, the fifth generation comprised the videos made most recently. Each generation, from the second to the fifth, contains 24 videos. They also correspond to a 6-week period since an average of 4 videos were produced and uploaded every week.

Comparing the percentages of strategies between the second and fifth generation we found that some strategies decreased. We found that in the most recent quarter the presence of educational games decreased considerably from 33% to 17%, while videos showing a teddy bear or hand puppet decreased from 38% to 17%.

On the other hand, other strategies increased. The presence of story books and reading aloud increased from 13% to 17%, showing students answering tickets increased from 13% to 29%, and showing activities completed by students increased

from 13% to 38%. Moreover, two strategies relating to imitation and improving successful strategies of other teachers also increased. Teachers explicitly stating that they used ideas from the first generation of videos increased from 13% to 33%, while teachers explicitly stating that they used ideas from other teachers' videos increased from 0% to 8%.

Table 2. Percentage of videos showing various teaching strategies.

Percentage	Description
96%	Shows the ConectaIdeas Express App
92%	Talks about ConectaIdeas Express and its benefits
72%	Shows a video that is very different from the others
56%	Shows the students' answers to the tickets
55%	Shows hand-written student responses in order to assess writing
55%	Shows concrete teaching materials
50%	Shows practical strategies that are easy to reproduce
45%	Shows activities completed by their students
44%	Shows videos they have produced to send to their students
41%	Considered very original by a panel of expert teachers
40%	Shows a teaching strategy that differs from traditional strategies
37%	Talks about the ConectaIdeas reports on student achievement
33%	Shows students answering tickets
24%	Shows a computer where the teacher receives the tickets
21%	Shows an educational game
21%	Shows a teddy bear or hand puppet
21%	Shows a story book and reading a story aloud
20%	Explicitly states that the idea came from one of the videos in generation 1
5%	Explicitly states that the idea came from one of the videos sent by another teacher
4%	Shows a member of the school's academic team
3%	Shows the teacher visiting their students' homes
3%	Shows the school's principal

There are some important limitations to this analysis of the changes that occurred between the second and fifth generations. First, since we only have 98 videos, the sample is small and the conclusions are not final. However, they show us a trend that needs to be confirmed next year with a larger sample. On the other hand, another limitation is that the videos may not show all the strategies that teachers use. In any case, given the quarantine in the country, it was not possible to go and visit the people in their homes and observe them in action.

6 Conclusions

According to a recent 2019 OECD report [50], pedagogical innovation among OECD nations has been moderate at the system level. The biggest innovations have been seen in independent knowledge acquisition and homework practices, followed by both rote learning and active learning practices. The report concludes that in order to produce good results, good pedagogical practices must be supported. Given this trend towards homework practices and the importance of the effect of parents, it is therefore critical to share effective teaching strategies for home use. In particular, these should be strategies that foster collective brains that connect with each other in order to explore, test, imitate, improve and recombine strategies, and thus discover new effective strategies. In this paper, we have described the implementation of a territorial learning ecosystem that provides teachers and parents with the facilities to support their children's learning at home, track the class progress according to the national curriculum, and network and share their experience with other teachers.

Given the unexpected appearance of COVID19 at the beginning of the school year, which meant only one week of face-to-face classes throughout the year, it is very encouraging that the ecosystem was adopted and 450,000 responses were received from students. A set of factors may have contributed to that number, such as the environment of the ecosystem, the ease of use of the App, and the gamification mechanisms to involve the community of students and teachers.

Innovation is a team sport [51]. Thus, the plan was to create a community and an ecosystem that fostered learning using an evolutionary mechanism for the transmission and improvement of strategies during the pandemic. Starting with a population of a first generation of videos with initial teaching strategies and how to complete tickets and send them to the teachers, the participation of teachers was encouraged by asking the most active teachers in the territorial ecosystem each week to produce videos of their strategies. In this sense, a precise metric was used to select the most active teachers. About one fourth of these teachers produced a 3-minute video and uploaded it to the ecosystem. The whole community was then encouraged to imitate and improve on these strategies. Two main mechanisms were used. One was to ask teachers to track the number of tickets per class and the curriculum coverage of their most active peers. A second mechanism was to activate the territorial mind of teachers, showing the number of tickets per school for their district, and comparing between districts and regions. The territorial learning ecosystem promotes territorial motivations. It includes an interactive map of the country, which displays indicators of the level of overall activity in the subject, as well as in each of the specific learning objectives defined by the national curriculum. The ecosystem displays indicators at four different levels: region, district, school and classroom. Both of these tools were used as gamification mechanisms.

The pandemic forced the community of teachers, parents and students to navigate a significant and very disruptive change. This change was even more difficult in first and second grade. However, the results indicate that a new form of remote teaching was gradually assimilated. The territorial ecosystem allowed isolated teachers working from their homes to improve the visualization of the progress of their students and compare themselves with other classes in their district and region. At the same time, the territorial ecosystem allowed principals, superintendents, and

authorities at the Ministry of Education to know every day and in real time what was happening with student learning.

Furthermore, comparing the distribution of strategies between the second and fifth generations of videos we found that some strategies decreased while others increased. We found that the presence of educational games decreased, as did the use of teddy bears or hand puppets. We also found that the presence of story books and reading aloud increased, as did showing students answering tickets and providing examples of activities completed by students. Moreover, two strategies relating to imitating and improving on successful strategies from previous videos also increased.

The system is currently being assessed by the Ministry of Education, with a view to being scaled to an estimated 70% of schools in 2021 for first, second, third and fourth graders, for both language arts and mathematics. This will give us the opportunity to observe new generations of videos, strategies, games and materials, as well as to verify whether the degree of enthusiasm and participation among teachers and parents persists and extends to other subjects.

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