The IDB and technology in education: How to promote effective programs?

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Executive Summary

Today, there is a general consensus about the fact that a high level of learning is important for economic growth. However, students in Latin America and the Caribbean have lower scores on standardized learning tests compared to other countries at similar stages of economic development, and much lower than that of the best performing countries. So how does the use of technology in education can help increase student learning? New technologies open opportunities to increase student learning and have the potential to reduce gaps between socioeconomic groups. Governments in the region, aware of the opportunities and challenges of technology, have made significant investments in increasing student access to computers and the internet mainly through delivery models like "one to one". Between 2006 and 2012, 20 of the 26 IDB member borrowers have promoted such initiatives and have distributed nearly 10 million laptops in public schools throughout the region. However, evidence suggests that infrastructure and technology are necessary but not sufficient conditions and should be geared specifically towards improving learning. The key question is: how can we design and implement effective technology to improve children learning? The objective of this technical note is to describe the principles that will guide the operational and analytical work of the Inter-American Development Bank (IDB) in the area of technology in education to promote effective programs that will enhance the skills of students in Latin America and the Caribbean.

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Content

Introduction

Students in Latin America and the Caribbean (LAC) obtain lower scores on standardized tests compared with other countries with similar economic development, and much lower than the best performing countries. The 8 Latin American countries that participated in the 2012 Program for International Student Assessment (PISA) are among the 14 lowest performers in mathematics out of 65, and many students do not reach basic levels of knowledge in math, science and reading (Bos, Ganimian and Vegas, 2013). This is one of the main challenges the region faces for increasing productivity and reducing levels of poverty and inequality in the coming decades.

Why emphasize the use of technology for improving student learning? The 21st century has been characterized by an explosion of technological changes in many areas, including production, commerce, the media, health and education. Expanding access to broadband Internet opens opportunities and challenges for each of these fields. The new century requires young people leaving the education system having mastered information and communication technologies (ICT) to perform successfully in the labor market. Moreover, these new technologies open opportunities for increasing student learning and narrowing gaps between socioeconomic groups.

The Sector Framework for Education and Early Childhood Development of the Education Division has identified five dimensions of success in high-performing countries in international learning assessments. One of these dimensions is that all schools should have adequate resources and the capacity to use them for learning, including technology. Latin America and the Caribbean need to improve their infrastructure and educational materials. The governments of the region are aware of the challenges and opportunities created by technology, and make sizable investments in this area to improve learning. In terms of infrastructure, considering activities realized and plans in execution, about 11 million laptops will have been delivered to students in public schools in the next few years (Severín and Capota, 2012). Although more difficult to quantify, significant investments have also been made in the region to train teachers and produce digital educational content.

However, the evidence suggests that infrastructure investments are necessary but not sufficient, and that they need to be complemented with content, teacher training and guidance about pedagogical uses. Using technology has to be adequately integrated with class work and aligned to the curriculum to enhance student abilities. The main challenge is to use the technology effectively to enable students to improve their learning in traditional areas, but also to acquire the digital skills needed to participate and contribute in the 21st century economy.

To reach this goal it is essential to work with the key actors in the learning process and coordinate their actions within education systems. First, teachers must have the support they need to make teaching more responsive to students' needs, and should be trained to teach in the new technological environment. The teacher has been, is and will remain the key actor in the education process. At the same time, the potential of technology should be used to improve the efficiency of schools and support school principals in their management and monitoring roles. Finally, technology can contribute to the goal that all students have access to quality education, even those living in remote rural areas. These actions will strengthen and modernize the educational systems and increase their effectiveness.

This technical note describes the principles that will guide the operational and analytical work of the Inter-American Development Bank (IDB) in the area of technology in education with the aim of promoting effective programs and, ultimately, improving skills of LAC students. The Bank has played a key role in this area and expects to continue to work along countries in the design and implementation of technology in education programs, both through operations and knowledge products. Through lending operations, the Bank will continue to support the region with the design, implementation, monitoring and evaluation of technology in education. With respect to analytical work, the Bank will continue to develop and support high-quality research aimed at deciding how to use technology effectively to improve student learning.

The first section of this note presents the conceptual framework used to describe the key inputs of technology in education programs and how these inputs can improve learning. This conceptual framework helps understand the logical chain of activities through which a program can produce impacts and it can be used to analyze and design a program, monitor its development and assess its impacts.

In technology in education programs, the core idea is that the technological resources available determine the use that teachers or principals give to them and this use in turn determines the impact on skills. Technological resources can be classified into three components: infrastructure (devices, connectivity, electricity, security, among others), content, and human resources (teachers, principals, parents and other community members). The *use* of technology is the critical link in the chain of events. Technological resources can influence the educational process and improve students' skills through two main transmission channels: the change in teaching practices and improved systems of school support and management. Finally, the main motivation for implementing technology programs is to contribute to developing students' skills, defined broadly. This note argues that the programs can affect three types of skills: academic, digital and general.

Different combinations of the three components of technology in education programs (infrastructure, content and human resources) can produce a variety of programs. However, this note highlights one classification motivated by the critical role that the use of the resources plays in the process. We consider that a program provides "guided use" if it specifically defines the target subject, the software to be used and the expected weekly use time. A guided-use program clearly defines the three "s": subject, software and schedule. In contrast, a "nonguided use" program provides access to technological resources but the user (teacher or student) must define the learning objective, the software or the frequency of use.

Section II discusses how access to technological resources has increased in the countries of the region and what the predominant uses are. An important fact is that ICT policies have been institutionalized in the education sector in the region. These policies were focused on the provision of resources: access to technology infrastructure is where the region has made most progress. While in 2000 the average number of students per computer in Latin America and the Caribbean was 56, in 2009 it was only 21 (Sunkel, Trucco and Espejo, 2013). However, countries have made less progress in content development and training of human resources and, especially, in identifying and disseminating effective technological uses. Regarding human resources, countries have concentrated their efforts almost exclusively on teacher training in basic ICT use, but with low coverage (only six countries have national programs and all report figures of less than 50% (Sunkel, Trucco and Espejo, 2013).

Evidence from PISA 2012 suggests that there is potential for programs that rely on ICT use at home and emphasize Internet in school. In particular, students reported to use Internet for school-related activities (such as homework) with the same frequency as recreational activities. In addition, the proportion of students engaging in activities with ICT in schools is less than any activity in the home, except surfing the Internet for schoolwork. However, the data on available resources and use of technology in Latin American countries is in general scarce. Improving and systematizing data collection in this area is crucial for adapting future ICT programs to the needs and conditions of the region’s educational systems

The world is experiencing the rapid adoption of technology in many areas. Section III of this note covers the most salient trends. Tablets have made a strong entry into the market and are rapidly adopted. Some initiatives are present around the world to supply tablets to all students at certain levels (for example, Thailand and South Korea). In the region, some governments are implementing pilots and initiatives for large-scale programs are emerging. Smart phones have also entered the market and could be a vehicle for educational applications. The variety of devices available means that in the next few years “bring your own device” initiatives could be adopted in the region. In addition, increased access to Internet (and broadband) generates significant innovations in content and educational applications.

Technological innovations also affect the labor market, educational trends and even the process of research and development to identify effective educational models. In the labor market, the demand for skills is changing. Some experts believe that skills related to creativity, critical analysis, collaboration and communication may become more valuable in a society that rewards innovation and teamwork. Likewise, knowledge in traditional areas, such as language and mathematics, will still be essential, because this is the basis for building important specific skills. In the field of education a strong constructivist stream has emerged, which emphasizes that knowledge must be built up by the student who guides his own education and works in a team, along with educational activities connected to the learning context. Although in the region, incipient attempts are present to adopt these practices, the empirical basis for these emerging models is still limited. Last, the United States Office of Educational Technology stimulates innovation clusters among schools, researchers and industry with the expectation these partnerships will speed up research and development in the sector.

The analysis in Section IV, focused on solid empirical evaluations, indicates that the impact on academic areas tends to be greater in programs that *guide* the use of technology resources than in nonguided programs. Moreover, programs that guide use tend to be more effective in improving learning in standardized tests compared with other educational interventions. In contrast, nonguided-use programs are among the least effective interventions. Furthermore, our analyses documents a high dispersion of the impacts of guided-use programs, larger than the dispersion of impacts of nonguided-use programs. This high dispersion suggests a need to experiment with various models of guided-use programs to identify those most effective.

There is a wide variation in the cost of programs. This variation mostly depends on whether students share technology or equipment. Shared programs, through computer labs or laptops in class, require fewer resources than one computer per student. Since guided programs usually involve sharing equipment, costs tend to be lower. This is also explained by the use of a limited number of applications (aligned with the learning objectives) and with staff training that focuses on specific tasks.

Section V reviews the operational and analytical activities on technology in education financed by the Bank in the last 15 years. This exercise analyzes where investments have been made, evaluates achievements and extracts lessons from this experience. In terms of lending operations, investments have been concentrated in programs aimed at expanding technological infrastructure access in LAC schools (computer labs and multimedia, mobile laboratories and "one-on-one" models). In general, these interventions have led to a nonguided use of technological resources. Recently two operations were approved to expand the coverage of secondary education in remote areas of Brazil through interactive distance education. In terms of knowledge production and dissemination, the Bank invested about US$15 million to fund 23 Technical Cooperation operations and 4 Economic and Sectoral Work (ESW) studies. These activities include support for operations and pilots, process and impact evaluations, generation of educational content, and support for events related to knowledge sharing and dissemination.

Based on the Bank's experience in the region, the evidence on effective uses of technology in education and successful experiences around the world, Section VI outlines the following principles to guide lending operations:

i. *Focus on specific learning objectives.* These could include basic areas such as language, math and science; digital skills; and certain core skills for the 21st century, such as creativity, critical thinking, communication and collaboration.
ii. *Coordinate three key components:* infrastructure, content and human resources. Investments in these components will have to be coordinated and targeted at the specified objectives.

iii. *Establish a strong monitoring and evaluation strategy.* Plan and implement actions to identify progress in implementation of the operations, the challenges and the impact generated.
iv. *Ensure progressive expansion and sustained efforts over time.* Technology programs require sustained investments to coordinate the actions of each component and build capacities of key actors.

In the analytical area, the Bank will support knowledge development and dissemination through Technical Cooperations and Economic and Sectoral Work studies that support governments on how to use technology effectively to improve student learning. The following principles will guide the analytical work in the area:

i. *Support for evaluations of promising programs.* The Bank will use its experience in the area to support countries in the region to rigorously evaluate promising programs.
ii. *Develop knowledge in prioritized areas.* To maximize the benefits of the evidence generated, the Bank will prioritize knowledge development in key areas where technology could have a greater educational impact and where common solutions at regional level can be identified.
iii. *Establish long-term projects.* To exploit the synergy created in research projects, long-term projects will be established which allow collaboration with governments, researchers and local implementers.
iv. *Promote knowledge sharing and dissemination.* The Bank will use its close contacts with countries, universities and research centers in the region to promote knowledge exchange and dissemination and maximize the educational impact of technology in education programs.

The Bank's actions in the operational and analytical areas will be closely coordinated. On one hand, the operational work must use the evidence on how to design and implement effective technology in education programs. On the other hand, the analytical work has to prioritize research in areas related to the main policy challenges identified by the countries and the Bank.

In both operational and analytical work, the Bank will work with the private sector to exploit opportunities for mutual benefit and cooperation. Several important actors operate in all the critical areas for implementing technology in education programs: infrastructure, content and professional development. Considering that collaboration is always subject to countries' needs, the private sector could operate with the Bank in three roles. First, as supplier of goods and services participating in procurement and acquisition under the relevant policies and procedures; second, as client in loan operations, receiving financing through the Bank's windows for the private sector; third, as collaborator in areas of social responsibility, in which strategic alliances or specific partnerships can be formed with financial or in kind resources, to support policy dialogue or knowledge generation. Collaboration in areas of social responsibility could happen through publications that reflect the industry's views on key issues or by cofinancing knowledge creation events or projects that generate evidence for decision-making in the sector.

Last, this note presents the main lines of action that will guide the Bank in this area over the next years. First, the Bank will promote experimentation with different models of guided-use programs to identify the most effective ones. Second, production of regional public goods will be prioritized in terms of software and translation of content that could be useful for the countries of the region (for example, translation of material from Kahn Academy). Third, the role and training of teachers will be emphasized to support their work in the new technological context, in accordance with the Sector Framework for Education and Early Childhood Development. Fourth, fluid communication will be maintained with the industry to identify potential areas of collaboration including producing inputs for designing technology projects and stimulating dialogue on public policy in the sector. Finally, because technology advances rapidly, the described principles and lines of action should be flexible and adapted to the opportunities and challenges.

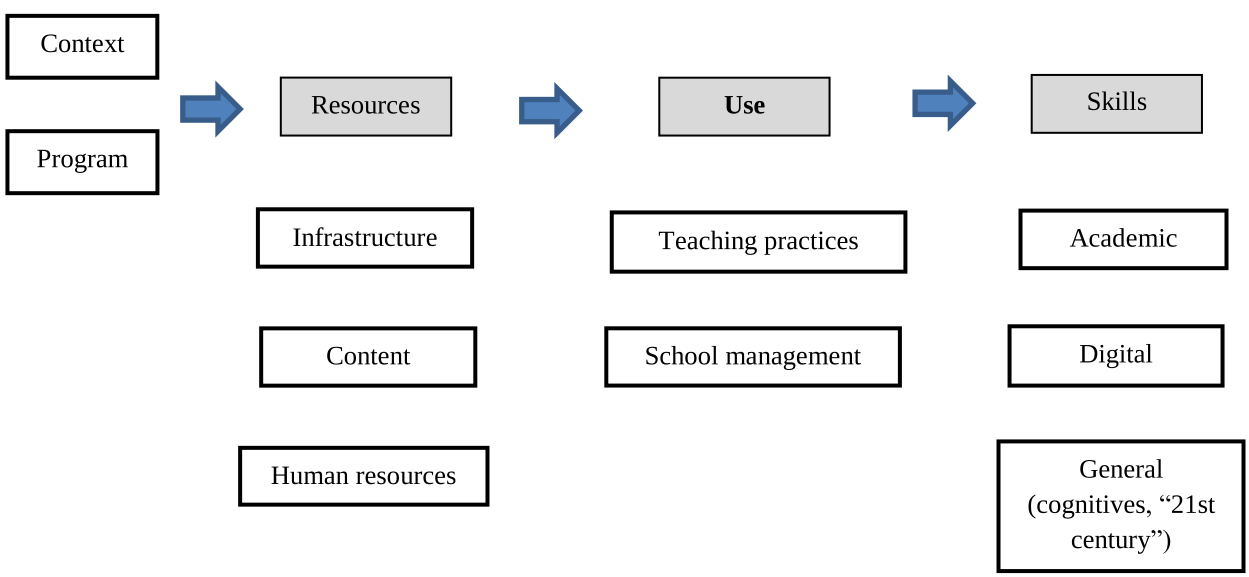
I. Conceptual framework and types of programs

This section presents concepts for analyzing how technology in education programs generate results. In the first part we propose a conceptual framework to summarize the key elements of a technology in education program and the associated logical chain to understand how it can affect students' skills. This framework shows that there could be a variety of programs that will emphasize different resources, uses and skills. In the second part we present a classification of program types based on whether users (teachers or students) are guided on how to use technology effectively or rather they have to find themselves how to use the technological resources.

A. Conceptual framework

A conceptual framework makes it possible to understand the logical chain through which a program produces impact. The framework can be used both to analyze the design of a program and to monitor its development and assess its impact. In technology in education programs, the central idea is that the technological resources available determine the use that teachers and students make of these resources, and this use determines the impact on skills. Next we present this conceptual framework and analyze its different components.

Figure 1: Conceptual framework



Resources

Technology in education programs, together with the initial context, determine the existing resources. The initial context includes the characteristics of students, teachers, families, principals, schools and communities. For each actor, there are multiple relevant areas including economic resources, capacities, experiences and attitudes. Based on this context, the program will perform a series of actions affecting available resources. The resources can be classified into three types: infrastructure, content and human resources (Severín, 2010).

Infrastructure. This component includes a series of resources needed for which users, both teachers and students, access technological devices that work adequately. In first place, these include desktops, laptops, netbooks, tablets, digital whiteboards, cameras and video players, smart phones or any device that can be used to support learning. In the region, the most used devices are laptops and netbooks but in recent years tablets and other devices have entered Latin American schools (see section III).

The physical environments where computers are used can be divided into two models. The first model includes computer labs. These are spaces where teachers can take their students and have them work with certain applications, usually in groups of two or three per computer. Almost all countries in the region have national programs that have deployed computer labs. Despite their popularity, some experts argue that this model could intimidate teachers (Sunkel, Trucco and Espejo, 2013).

A second model that has emerged in recent years is the use of laptops in the classroom. This includes both "one on one" models and mobile labs. One-to-one models (also 1:1, 1-1 or 1 to 1) refer that each child is assigned a device, usually with Internet access for educational purposes. Mobile laboratories are laptop carts, which can be moved to the classrooms where they are needed. As with computer labs, the teacher must plan the use of the technology, but in this case the laptops can be used in the classroom when appropriate. Mobile laboratories have the advantage of being an intermediate model: it does not require students to go to a computer lab, and it costs less compared with providing each student with a computer.

The second main infrastructure element is connectivity to either an internal network or Internet. Access to the network makes tools to develop different skills available to students, such as searching for information, accessing software and materials online, and using communication platforms. However, Internet access, particularly fast connection, is still a challenge for many LAC countries. Many rural or isolated areas still lack connectivity and in others where it does exist it is often slow and expensive (IDB, 2012).[2] An alternative is for schools to have efficient internal networks, and for local servers to have material that students can find and share.

The third main infrastructure element includes the resources needed for the normal functioning of the devices, such as electricity, adequate physical space, furniture, security measures and technical support.

[2] For this reason, the IDB launched the Special Broadband Program in March 2013 with the objective of creating an institutional and regulatory environment conducive to competition and investment and development of public policies to speed up and expand access, adoption and use of broadband services. This program devotes substantial resources from the Bank's Ordinary Capital to promoting high-speed connections throughout the region.

Content. Digital content includes educational software, applications, platforms and portals. Educational software consists of applications focused on curricular subjects. Cheung and Slavin (2013) classified technology programs for learning math into three groups. First, there are supplementary computer-assisted instruction programs with individualized tutoring adapted to the level of the student, in addition to regular teaching activities (for example, *SRA drill and practice).* Second, in computer-managed learning programs, the devices are used to evaluate the skills of students, assign material appropriate to their level and monitor their progress (for example, *Accelerated Math*). Finally, comprehensive models include instruction to students through the computer and activities with the teacher without using technology *(Cognitive Tutor).*

Some educational tools and applications are not directly oriented to learning a specific academic subject. Some programming languages have been developed to stimulate creativity and problem-solving skills, such as Logo. There are also applications designed to improve general cognitive processes, for example, memory, attention, reasoning, speed and flexibility, such as those available at www.lumosity.com.

Internet has opened up access to a wealth of material including web pages, digital books, videos, animations, sound and images. In recent years Web 2.0 tools have appeared, which allow users not only to access but also to produce web content (for example, Blogger, Wordpress, YouTube, Twitter, Slideshare and Wikipedia). These tools can be used to encourage research, creativity, communication and teamwork.

Finally, some applications facilitate communication and learning management. Educational platforms provide teachers with services such as file management, communication with students, and opportunities for collaboration and discussion in forums and chats. These tools facilitate their tasks, and automate certain processes, which saves time and improves communication. Some of the most commonly used learning platforms are Moodle, Blackboard and Claroline. The educational portals give teachers, parents and students simple and rapid access to educational resources. The portals have been an important resource for sharing knowledge, experiences and practical guides.

Human resources. All technology in education programs take place in a multidimensional context, and, therefore, require a joint effort by the stakeholders in the educational system: teachers, families, principals, schools and communities. The participation of all of them is essential for stimulating the use of technology, facilitating integration of technological materials in the classroom and the home, and creating a favorable environment for developing teaching practices that exploit the comparative advantages of technology.

In recent years the professional development of teachers has been recognized as key to incorporating technology into learning. Teachers often determine the time of use of the technology, the applications used and how they are integrated with other educational activities.

Therefore, it is crucial to develop teachers' capabilities to help them make appropriate use of technology. There are three dimensions of capabilities that can be developed:

a. *General*. Competence to operate a computer, manage files, use productivity software (word processors, spreadsheets, production of presentations) and Internet tools such as browsers and e-mail. With these capabilities, teachers can incorporate technology into their planning, administrative activities and communication with parents, students and peers.

b. *Use of a specific software*. The capacity to use software targeted to a specific academic area. The training focuses on knowing how to use the application and solve any problems that may arise. The time needed to develop this capacity will vary with the application, but is generally relatively short given the limited objective.

c. *General educational use*. General knowledge of various educational applications that can be used for different subjects and grades, along with appropriate teaching strategies. Because of their wide scope, they generally require a longer training period.

There are different activities that can improve teachers' capabilities including pre-service training and in-service training and support. Technology in education programs use both training activities led by a facilitator outside of the classroom, and direct pedagogical support in the classrooms.[3] Last, the creation of learning communities, supported by the use of technology, is a promising strategy that allows teachers with common interests to share experiences and solutions.

At the school level, the principal is responsible for fostering an environment favorable to the integration of technology in instruction and facilitating access to technological resources. The joint work of teachers and principals, and the motivation, leadership, training and definition of the role of principals are critical for successful implementation of technology programs (Fullan, Watson and Anderson, 2013). However, so far there is little evidence on the capabilities of principals, which need to be reinforced, and few interventions in the region have targeted school management teams.

Finally, the community and parents also have an important role to play. Different programs distribute laptops, which in many cases are owned by the students and teachers, and permit their use at home and in the community, as well as in the school environment (Sunkel, Trucco and Espejo, 2013). By providing access to digital tools and the Internet for families and communities that would not have access otherwise, new technologies can have a transformative effect. This requires information and socialization actions to avoid resistance or confrontations from the education community.

[3] The technology is also being used for teacher training activities. For example, with the help of cameras and Internet, teachers can be obtain information live from an instructor or colleague who could be in the room next door or online anywhere in the world (see section III).

Use

The use of the technological resources is the key link in the chain of results. The provision of technological resources can influence the educational process and impact students' skills through two main transmission channels: a change in teaching practices or an improvement in support systems and school management.

The provision of technological resources can to lead to improved learning only with enough and efficient use of these resources. For this efficient use to occur two conditions should be met:

- *Quantity: the technology is used*

For technological resources to improve pedagogical processes and school management, they have to be used. If a program delivers computers which are used only marginally for learning in a certain area (for example, math), it is not realistic to expect impacts. In contrast, excessive use of technology could reduce the time available for activities that may have a greater educational impact. So it is important to use evidence (or experience in its absence) to decide appropriate length of time that technology is used. During monitoring, the analysis of time use gives powerful information for determining potential impact. Gathering data on time use in activities related to different areas helps determine what impact can be expected.

- *Quality: the technology is used exploiting its comparative advantages*

The effective use of computers for improving pedagogical practices or to support certain school management processes is a necessary but not sufficient condition to generate impacts. To have a positive impact on skill development, the use of technology needs to generate more learning compared with that produced by traditional instruction. That is, quantity of use is necessary but quality of use is also critical. If computers are used for tasks where they do not have comparative advantages, it is unrealistic to expect a positive impact. For example, if computers are used to take notes from the blackboard, there is no gain over a pencil and a notebook. Moreover, there could be negative learning impacts if its use requires significant setting up and troubleshooting activities not needed when traditional resources are used. The new technologies have many comparative advantages, which depend on how they are integrated into the education system. Some comparative advantages are related to the pedagogical practices while others relate to uses focused on improving school management. These comparative advantages are described below for both uses.

Pedagogical practices. Certain technology in education programs aim to foster changes in pedagogical practices to produce improvements in learning. To generate learning impacts these programs need to exploit the multiple advantages that the use of technology for educational purposes has that include:

- Motivation: children are naturally attracted to technology; their interest increases.
- Presentation: allows use of attractive educational videos and simulations.
- Customization: content and exercises can be tailored to the level of the student.

- Feedback: students can receive immediate feedback based on the answers they provided.

The use of computers, as it relates to regular instruction by teachers, can take two forms. The technology can be incorporated in a *supplementary* way. The use of computers supplements the work of teachers without requiring a close coordination with the classroom teaching activities. The technology can also be used in a *complementary* way. In this case, there is a close planning and coordination of teaching activities in which computers and traditional resources are used. There exists educational software to support the use of technology in a supplementary or complementary way. Complementary use allows better integration of activities with and without the computer, but requires rigorous planning and implementation. The most effective type of use might depend on existing resources and the capacity, experience and attitudes of teachers regarding the use of technology.

Access to broadband Internet allows implementation of new ways of learning. It can be expected that use of technology will support collaborative learning in virtual environments. With broadband Internet, intranets and networks in schools, virtual teaching environments can be set up which could complement or even replace classroom work (Sunkel, Trucco and Espejo, 2013).

Last, computers connected to the Internet can provide attractive and educational content for students in their homes. The use of technology could transfer classroom tasks to the home, making it increasingly important for parents to get involved in guiding their children's educational activities in the home. This is the basis for the *flipped classroom* model, an educational initiative that has attracted much attention worldwide, promoted by the Khan Academy, a nongovernmental organization. In this model, students watch high-quality instructional videos in their homes and spend class time analyzing practical problems and discussing and reviewing concepts.

Support and school management systems. The increase in the use of technology for pedagogical purposes must be supported by a more general transformation of the school environment. It is possible to use technology to improve school management thought there is a need to adapt the overall system to the new technological context. This will include the definition of new technological standards and evaluations, curriculum improvements and professional development for teachers and principals, among others initiatives (Partnership for 21st Century-Skills Task Force, 2007).

With respect to school management, there is limited quantitative evidence of the benefits of incorporating technology to improve processes; even so, successful experiences have been documented in which technology offers significant comparative advantages. These comparative advantages are related to the following areas:

- Information: facilitates access to information, saving time and improving lessons; it can also help teachers and principals with planning activities and the analysis of data on students and teachers.

- Communication: allows easier communication among teachers, students, parents and principals.
- Collaborative work: favors collaborative work among teachers (sharing study plans and lesson preparation) and among teachers and the management team (students at risk of dropping out or repetition at system level, management of teacher training).
- Teacher training: reduces costs and makes training and peer collaboration more flexible; facilitates access to professionals and international experts, courses and online training.
- Monitoring: generates data on learning, attendance, evaluation and task records, which allows corrective action by parents, teachers, principals and administrators; facilitates measurement at national level with online examinations and teacher evaluations.
- Administrative management: supports management of inventories, purchases and payments, and staff management, among others.

The comprehensive introduction of technology can change the overall education process, at both the system and classroom level. These changes have to be phased in and coordinated to create synergies between the different initiatives. To maximize the potential of technology in system management, it is advisable to train principals and teachers to ensure that the collected information is used in the best possible way. However, initiatives in the region to provide training courses for school management teams are only starting (examples of these initiatives are presented in Section II).

Skills

The main motivation for implementing technology in education programs is to contribute to the development of students' skills and to raise the quality of education in the region. Fostering the development of human capital can increase the productivity of the labor force in future generations. Based on the available evidence, it is expected that programs can affect three types of skills: academic, digital and general.

Academic. Subjects such as math, language or science are part of the curriculum in Latin American and Caribbean countries. As mentioned, students from LAC countries are outperformed by their counterparts in countries of similar level of development. Moreover there are significant differences in results between students from different socioeconomic levels within countries. In general, the use of technology can improve students' academic skills and, in particular, programs that focus on low-performing students can reduce both the dispersion of educational results and the gaps between groups.

Digital. Digital skills refer to the capacity of students to use computers for work, find information, communicate and become part of a society where technology is fundamental. These skills involve the ability to use different devices (computers, smartphones and tablets), operating systems, programming languages and applications.

General. General skills are not directly related to traditional education (academic) or to skills related to operate technology (digital). They include general cognitive, socio-emotional skills and the so-called 21st century-skills. General cognitive skills are measured using psychometric intelligence tests to elicit information about, among different dimensions, abstract nonverbal reasoning capacity (for example, Raven test), processing speed (for example, coding test) and spatial skills. Socio-emotional skills include self-control, motivation, perseverance and interpersonal skills. Lastly, there are skills related to learning and leadership that are considered essential for the 21st century, characterized by the globalization of the economy, the growing role of services and teamwork. These include skills relate to creativity, critical thinking, communication and collaboration.[4]

There are other effects that technology in education programs could produce. For example, a program to provide laptops could influence attitudes, expectations, activities in sports, socialization habits and incidence of health problems (for example, overweight). These programs can have a significant effect on social inclusion by providing access to digital tools and the Internet to families and communities that otherwise would not have them, and can affect the resources, behavior and skills of other people in the household (parents, siblings). Although it is important to understand these effects, this note focuses on the three types of skills described above because they are central to building human capital and because of the limited evidence of clear effects of other dimensions.

B. Types of programs

There is a great variety of technology in education programs which differ in the resources they provide, the use they promote and the skills they aim to improve. However, a key aspect of technology in education programs is the guidance that is provided regarding the use of the technological resources provided. On this basis, programs can be classified according to whether there is clear guidance on the frequency and type of expected use (guided use) or whether teachers and students decide for themselves how the resources will be used (nonguided use).

We consider that a program guides use if it specifically defines the target subject, the software to be used and weekly use time. A guided-use program clearly defines the three "s": ***s**ubject*, ***s**oftware* and ***s**chedule.*

In contrast, a nonguided-use program gives access to technological resources but the user (teacher or student) must define the learning objective, the software involved or the frequency of use. The direct objective of this type of program is to provide technological resources. The key resource is the provision of infrastructure, although they also typically include content production and teacher training. Since the resources provided could be used in various ways, these programs can have an impact on digital, academic or general skills.

[4] See the Partnership for 21st Century Skills website: http://www.p21.org.

Examples of each type of program are described next. The intervention that delivered personal laptops to students and teachers in multigrade rural schools in Peru can be considered a nonguided use program. The program did not specify the subjects to be improved. It provided access to digital content (there were 39 applications in the laptops) but did not specify which should be prioritized. Likewise, it did not specify the schedule for use of the laptops in class (Cristia et al., 2012). In short, the program did not guide the use of the technological resources provided. In contrast, a program implemented in India aimed to improve math learning of fourth graders through a guided intervention (Banerjee, Cole, Duflo and Linden 2007). Software aligned with the curriculum of this subject was installed with the instruction to use the computers for two hours per week, one during school hours and one before or after school. The subject, software and the schedule of use were all clearly defined, that is why it can be classified as a guided-use program.

The reason for classifying the programs as of guided- or nonguided-use stems from the evidence of one of the fundamental challenges of many technology in education programs: many teachers have serious difficulties in finding effective uses for the devices. At first sight, it might be thought that the ideal situation was to provide technological resources (computers and Internet, content and training) and then offer teachers flexibility so they can find the most effective use for themselves, in line with the learning characteristics and challenges of their students. However, often this ideal situation does not occur because researching, planning and implementing the use of technology in the classroom is a heavy extra load for teachers.

Identifying effective uses of technology involves a sizeable fixed cost. Finding effective ways to use the technology for a specific learning objective requires understanding the curriculum, researching different applications, finding the most appropriate ones and determining how long (and in what sequence) to use them. Ensuring that this complex task is properly carried out could make guided-use programs more effective. Guided-use programs can also incorporate coordinators especially selected and trained to support students in using technology. This frees up teacher time, which they can use for preparing classes, administrative tasks or even providing instruction in small groups for students who require special attention.

Table 1: Types of technology in education programs

	Nonguided use	**Guided use**
Prioritized **Resources**	Infrastructure	Content, people
Use	Determined by teacher/student	Predetermined
Skills to be developed	Not specified	Specific

The design, implementation, monitoring and evaluation of these two types of programs have important differences. Overall, the design of nonguided-use programs focuses on solving technological problems so resources can be used normally. This requires solving the problem of distribution of computers, continuous access to electricity and Internet, and setting up effective technical support schemes. In contrast, the design of guided-use programs focuses on solving educational challenges, including the definition of learning objectives and curriculum, software, and frequency and type of use.

Nonguided-use programs can provide a standard package of resources, such as computers, Internet, a catalog of digital educational resources and a general training for teachers in the use of technology. In contrast, guided-use programs require defined solutions for each grade-subject-context. The design of a guided-use program requires understanding the teaching challenges, how the technology will be used to solve them and a clear definition of the educational activities, software to be used and schedule.

The additional effort required by guided-use programs in the design stage is also present during implementation and monitoring. Since guided-use programs must produce specific solutions, their implementation requires planning and much more elaborate and detailed logistics. Monitoring is crucial for guided-use programs, because these activities need to check if the use proposed in the design has materialized in reality. Monitoring can consolidate information on use and results recorded by computers to focus teaching support on the schools, grades or subjects with most difficulties during the implementation. It is important that privacy concerns are met during the collection and use of these data.

The evaluation of guided-use programs is simpler than nonguided-use programs. Because the former clearly define the expected use of computers and the areas of impact, it is possible to contrast expected with actual use and check the effects in the focused areas. In contrast, the evaluation of nonguided-use programs is more complex because there is no "model" of use that can be compared with the practices observed in the field. In addition, the impact areas that the program is more likely to affect are not always defined. Therefore, evaluations of guided-use programs are usually concentrated on a few focused areas, while evaluations of nonguided-use programs typically analyze effects on a range of dimensions.

An ideal sequence of implementation can involve, in a first stage, a nonguided-use program, and then a series of guided-use programs with specific learning objectives. This would ensure a first phase that provides access to technological resources (computers, Internet, electricity, technical support) and develops a basic level of competence and familiarity of teachers and students using these resources. In a second phase, efforts would focus on the design and implementation of educationally sound solutions to guide teachers and students to use computers effectively, exploiting their comparative advantages.

II. Access and use of technology in LAC education systems

In the knowledge economy, technology has a central position because of its potential to process information, transmit knowledge and improve learning. Today, more than ever, policymakers seem to agree that better access to technology in education can promote economic growth through its effect on the educational system via improving learning, providing students with new skills, strengthening teacher training and reducing the cost of providing education (UNESCO, 2013).

This is reflected in the increased institutionalization of ICT policies in the education sector. According to a report from the United States Department of Education, most industrialized countries have national educational technology plans and have the vision to integrate ICT into primary and secondary education, either in independent documents or in ICT strategies between sectors (Bakia, Murphy, Anderson and Trinidad, 2011). A similar trend is taking place in Latin America and the Caribbean where the introduction of ICT into education has increased attention in the last two decades. This has led to national agendas in the sector and growing allocation of national resources: 13 countries in the region had an ICT policy for the education sector in 2010 or were in process of defining one (Sunkel, Trucco and Espejo, 2013).

Many LAC countries have implemented ICT policies in the education sector, but what is the degree of incorporation of ICT in the education system in the region? According to experts, so far national ICT strategies have focused more on providing resources rather than on implementing uses of technology in the school (Sunkel, Trucco and Espejo, 2013). The resources provided have almost exclusively focused on providing access to technological infrastructure, leaving development of educational content and human resources in the background. Unfortunately, little comparable cross-country evidence is available to measure progress regarding content production and, especially, for teacher training.

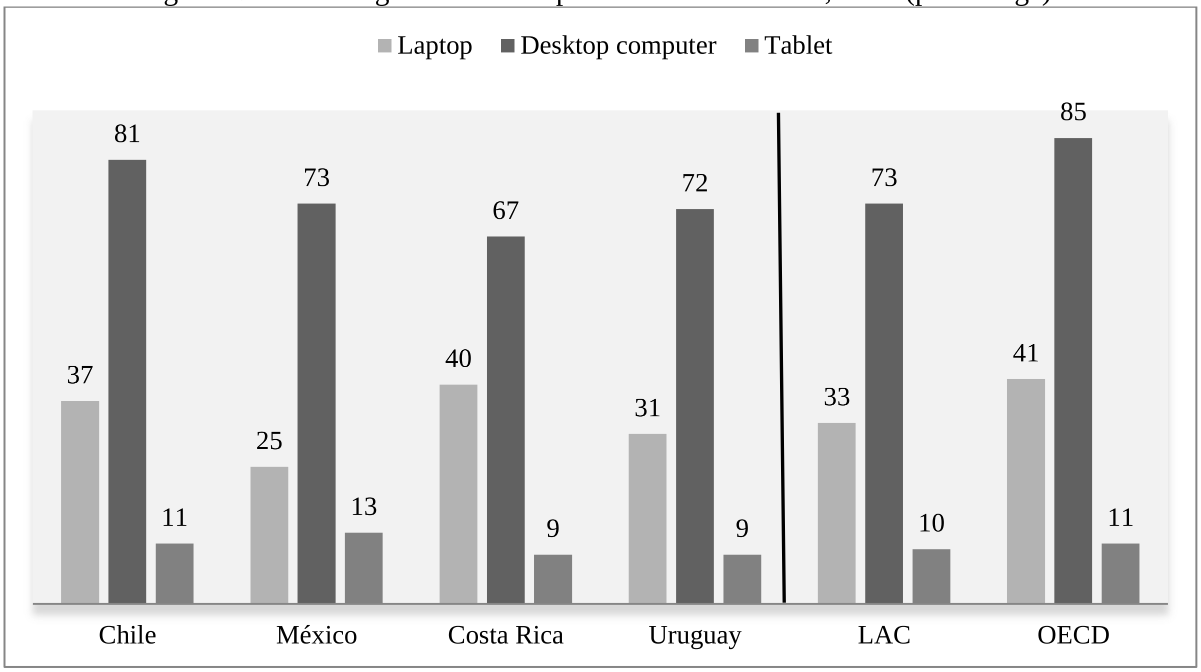
A. Resources

Infrastructure

There has been a substantial expansion in the availability of computer equipment in schools in the region. While in 2000 62% of students aged 15 in Latin American and Caribbean countries that participated in PISA attended schools with at least one computer available for academic use, that figure rose to 93% by 2009. As shown in Figure 1, access to this type of technology is supplemented in schools with laptops and tablets.

Another key indicator for measuring students' access to technological resources is the number of computers available per student. As shown in Figure 2, in the year 2000, educational institutions in the region had an average of one computer for every 56 students, compared to an average of 11 students per computer in the countries of the Organization for Economic Cooperation and Development (OECD). By 2009 that figure had changed to a ratio of 21 children per computer. This improvement in access reflects public policy efforts to invest in ICT in the education system, given that most students in the region attend the public school system (Sunkel, Trucco and Espejo, 2013). The increased access to computers should be evident at primary level because most countries have targeted initiatives to provide one laptop per student mainly at this level (see Annex III).

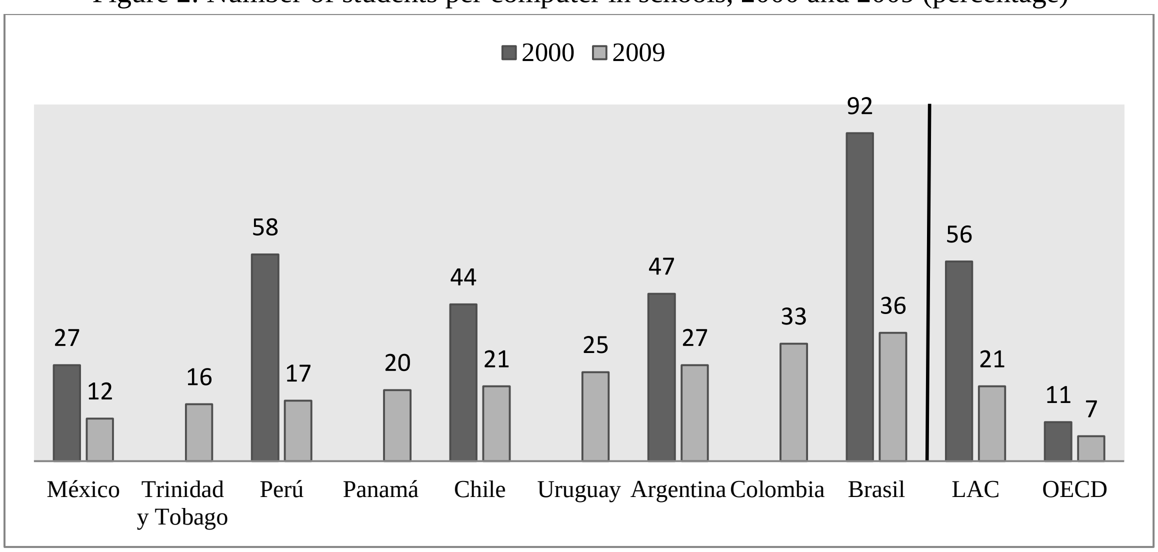
Figure 1: Students age 15 with computer access in schools, 2012 (percentage)*



Source: Own calculations based on data from the Program for International Student Assessment (PISA) 2012

* The Latin America and the Caribbean average is calculated only for the countries included in the chart.

Figure 2: Number of students per computer in schools, 2000 and 2009 (percentage)

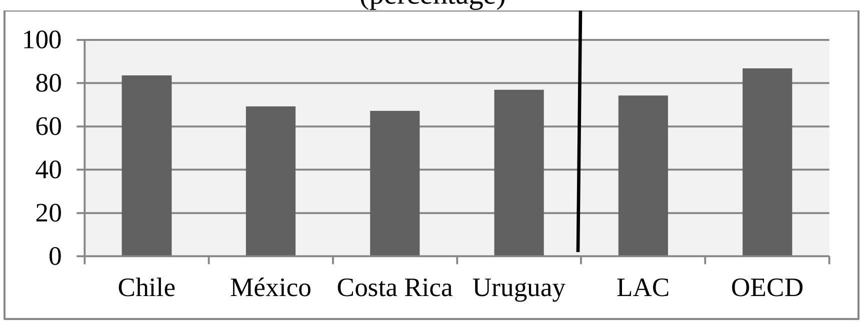


Source: Sunkel, Trucco and Espejo (2013) based on data from PISA 2009 and 2000.

* The Latin America and the Caribbean average is calculated only with the countries included in the chart.

Finally, another important measure of ICT infrastructure for education corresponds to the availability of Internet access in schools. Figure 3 shows the proportion of students that attend a school with access to Internet-connected computers. Internet coverage in the four countries from Latin America and the Caribbean which participated in PISA is high. However, some variation across countries is present. In Chile levels are above 80% comparable to those of the OECD, while in Costa Rica only 67% of students have access to Internet-connected computers at their school. Because access to Internet can provide several important pedagogical and management advantages, connecting all schools to the Internet is a basic medium-term goal for many countries in the region.

Figure 3: Students aged 15 with access to an Internet-connected computer in school, 2012 (percentage)



Source: Own calculations based on data from PISA 2012.
* The average for Latin America and the Caribbean is calculated only with the countries included in the chart.

Data disaggregated by type of Internet connection is important because they inform on the capacity of schools to engage in online activities that require broadband, such as streaming video, simultaneous two-way communications (for example, videoconferencing), or integrated applications with high capacity requirements (UNESCO, 2013). However, there is little consistent information in the region about this important dimension.

The positive view on the region's progress in terms of access and availability conceals the wide gaps that persist between socioeconomic levels. Inequality in access to ICT extends to the homes and school systems in most countries in the region. Higher-income students tend to have higher access to Internet-connected computers in school than those from lower-income segments. However, schools can help narrow the digital divide, since the access gap is smaller than in homes, and even has disappeared in some countries of the region as a result of public policies implemented in recent years (Sunkel, Trucco and Espejo, 2013).

Finally, the real access to ICT also depends on the availability of complementary infrastructure resources such as the physical space, furniture, continuous electricity and a reliable technical support. In particular, the models of technology integration in the schools in relation with the place of use and ratio of devices to students (computer labs, mobile digital labs and one-to-one models) can affect the real use of the technology. Therefore, we proceed to describe trends in the region about this dimension.

Most countries in Latin America and the Caribbean have implemented computer labs starting with pioneer initiatives in Costa Rica and Chile in the early 1990s. The Bank gave financial support to Caribbean countries from 1998 to 2005 to set up computer labs in their schools (see Section V). However, in the last 10 years models of ICT use in the classroom have gained popularity in the region.

Argentina, Brazil, Chile and Mexico have implemented experiences with mobile laboratories. An initiative of this type was recently launched in Argentina at primary level with financial support from the IDB. Moreover, of the 26 IDB member borrowers, 20 implemented a one-to-one computer initiative between 2006 and 2012 (see Annex III). Most of these initiatives, 12 out of 20, have been at the national level to equip every child in the country with a computer in one or more primary or secondary school grades: Argentina, Bolivia, Brazil, Chile, El Salvador, Guyana, Honduras, Panama, Peru, Trinidad and Tobago, Uruguay and Venezuela. The cases of El Salvador and Bolivia are different: in the former the intervention was restricted to schools with limited resources and in the latter the program was intended only for teachers. In other countries, the initiative was implemented as a pilot program in some schools or localities (Colombia, Costa Rica, Ecuador, Haiti, Nicaragua, Jamaica and Mexico). In Paraguay, the initiative was implemented in only one district (Caacupé).

The devices used hardly vary between countries. Almost all projects reported two types of devices: the XO laptop produced by the organization One Laptop Per Child (OLPC) is the most used (using only the Linux operating system), followed by Intel Classmate PC. Only in Bolivia, Chile, Guyana and Trinidad and Tobago did programs use netbooks or notebooks from other manufacturers (Lenovo, Haier or HP).

As it is described below, the IDB directly supported these programs in seven countries: Brazil, Colombia, Haiti, Honduras, Paraguay, Peru and Uruguay. The Bank provided technical assistance to countries, while for Uruguay and Honduras the Bank approved lending operations in 2009 and 2011, respectively. The content of the projects varies by case: the IDB funded only evaluation activities (Brazil and Peru), evaluation accompanied by content development or teacher training (Colombia, and Uruguay), or provided full funding of programs including purchase of equipment, servers, training and evaluation (Honduras, Haiti and Paraguay).

As Severín and Capota (2012) emphasize, despite the growing popularity of the one-to-one initiatives, many of these programs were implemented when little was known about their impact on learning and there was little evidence on how to structure the programs for increased impact. This would explain why some projects have had disappointing implementation or impact. The experience of the region in this area highlights the need to produce strong evidence to identify models of effective uses of technology, which can improve students' learning.

Content

The provision of digital content is a necessary condition for the effective use of the new technologies in schools. There are different aspects related to content that are necessary to define in a technology in education program. First, it is necessary to perform initiatives related to the implementation and adaptation of the curriculum content of ICT or their cross-cutting use to support different subjects covered in the curriculum. Second, digital material for teaching and learning with technological tools should be provided including encyclopedias, manuals, textbooks, guides and videos. Third, it is useful to provide software to support teaching and learning processes including productivity applications, platforms and virtual simulators. Finally, software should be provided to support the implementation and adoption of management systems for information (for example, education portals) and for systems to monitor different aspects including educational projects, study plans, teaching methods and potential use models. What is the degree of progress in Latin American countries on these four activities of content development?

The first aspect – adapting ICT curriculum content – is crucial to the design of a technology program that provides teachers with a logical framework that enable them to improve the learning process using technology. Most countries with large-scale technology in education programs have introduced these initiatives to some extent. Twelve countries in the region had an ICT policy for the education sector in 2010 or were in the process of drafting one (Sunkel, Trucco and Espejo, 2013). Bolivia, Chile, Colombia, Guatemala, Mexico, Nicaragua, Paraguay, Peru and Uruguay have an officially published policy while Costa Rica, El Salvador, and Panama were completing their development process in 2013.

For points 2 and 3 – development of software and digital material for teaching – there are no reliable data in the region to quantify these initiatives. However, some experts recommend not creating new resources for each technology program because development and production of educational software can be expensive. In the early stages of projects or in pilot projects, it is advisable to use the existing software, if it is possible to adapt it to the context and the program (Osin, 1999). According to Osin, the development of educational software is justified at the local level when there is enough experience and when the programs needed will not be provided by foreign companies, such as those related to national geography, history or specific challenges. In LAC, educational software and digital material developed abroad is rarely used because of difficulties related to identifying effective resources and translating them. Countries could work together to increase access and use of high-quality material with proven effectiveness.

Finally, the countries of the region have focused their ICT content policy on the fourth aspect related with information management systems by creating educational portals to make new educational content and new tools available as public goods accessible to all students, teachers, administrators and families (Sunkel, Trucco and Espejo, 2013).

Although there are no comparable indicators on content production, data available on educational portals suggest that almost all countries in the region have introduced them to facilitate sharing content and knowledge. The first portals came out between 2000 and 2001 in Argentina, Brazil, Chile, Mexico and Peru; today 19 countries in the region have portals (Sunkel, Trucco and Espejo, 2013). An important regional initiative was the creation of the Latin American Network of Educational Portals (RELPE) in 2004, with IDB support. The goal was to build a community to share and collaborate in the production of high-quality educational content. The initiative was aimed at improving the quality and equity of education in Latin America through the effective integration of ICT in education processes, respecting each country's national identities and policies.

These education portals present different characteristics and can be classified into two groups. The first group includes portals with 2.0 tools that offer users forms of communication and tools for creation and dissemination of information in social networks. The second group contains portals that allow downloading available resources or content to support education but that foster limited capabilities for interaction. Offering teachers tools for communication and sharing of experiences and materials could be important for changing teaching practices. Unfortunately there are no statistics on the actual use of these portals, so it would be useful to survey users or at least record information on the volume of downloads.

Human resources

Experience suggests that to change practices and educational outcomes it is essential to prepare, train and support the actors involved technology in education programs (Severín, 2011). These actions can be grouped in three areas: i) teacher and management training, including general skills (use of ICT, basic training and productivity and communication tools) and specific skills; ii) efforts to provide teaching support and follow-up for participants including the establishment of professional learning communities among teachers and collaboration networks; and iii) actions to promote active community participation in projects.

Teachers have a key role to play in the successful implementation of projects. In the region various models for professional development of teachers have been implemented to integrate ICT into educational processes. However, implementation of teacher training activities has so far been limited (Sunkel, Trucco and Espejo, 2013). Only six IDB member countries provide information on the percentage of teachers trained in ICT use, and all report figures below 50% (Argentina, Costa Rica, El Salvador, Mexico, Peru and Uruguay).

B. Use of technology in the educational process

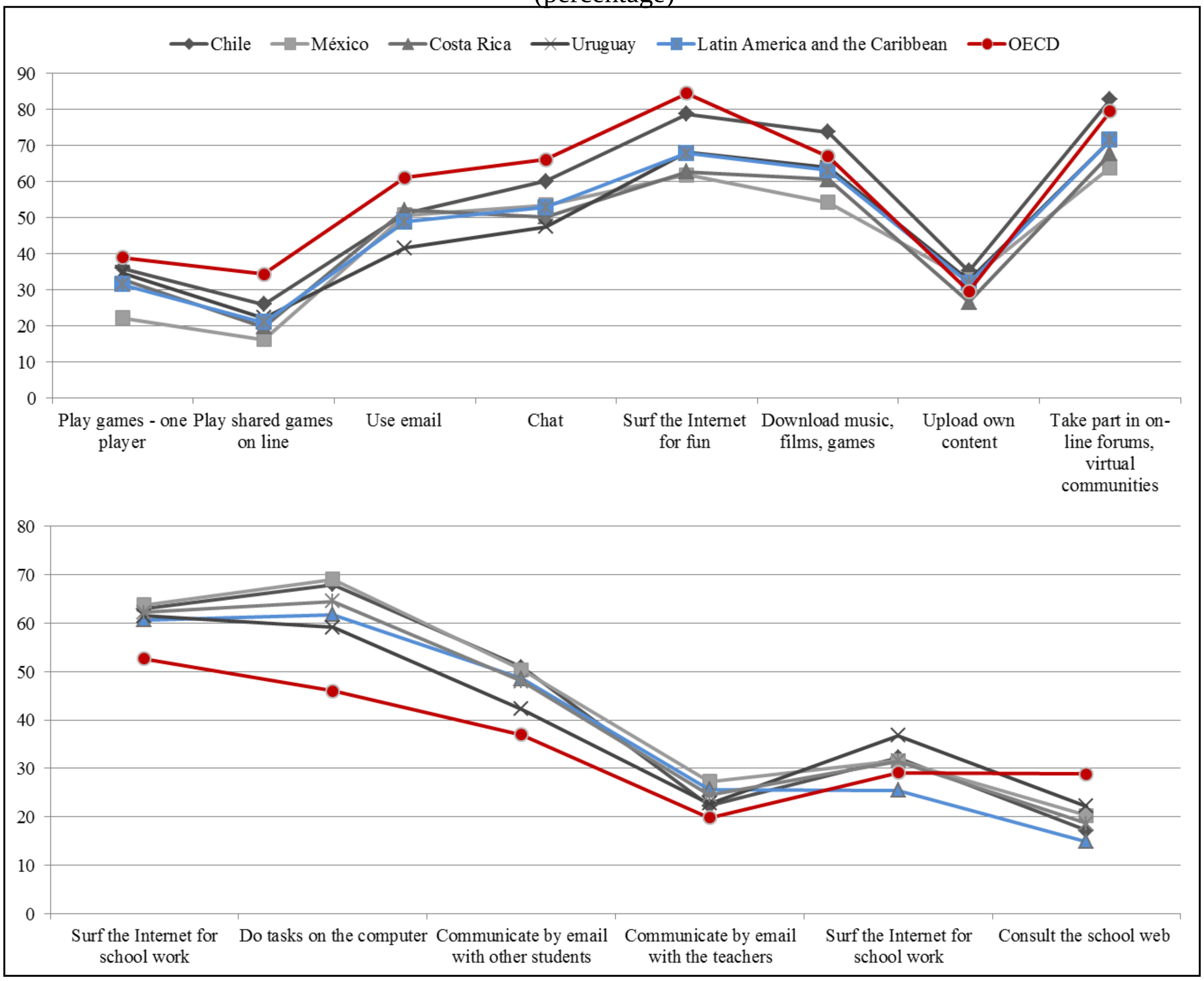
As noted above, technology in education programs can improve students' skills through changes in teaching practices and improvements in school management. The previous subsection documented how access to technology for educational purposes had increased in the last 10 years in the countries of the region. However, what is its effective use? How do teachers, students and other actors exploit these large investments to expand access?

Pedagogical practices. According to the report on ICT use in PISA 2009 (OECD, 2011), students use technology at home mainly for recreation and communication purposes, including surfing the Internet, chatting or downloading music or movies and sending e-mails.[5] As the top panel of Figure 4 shows, between 50% and 80% of students in Mexico and Chile, and 40% and 70% in Uruguay and Costa Rica, said they frequently engage in these activities.

However, students also reported engaging in some educational tasks with the same frequency as recreational ones. In the four countries in the region which participated in the study, more than 55% of students mentioned doing homework on the computer, a higher percentage than the average for OECD countries (bottom panel of Figure 4). Claro, Espejo, Jara and Trucco (2011) argue that if these results are common student practices, they would open the way to many interesting applications that can be stimulated from schools to induce children to develop more complex ICT-related cognitive skills. Finally, interaction between students and teachers through e-mail is not common: less than 30% of students said they frequently used this method. Although this might suggest that ICT use by teachers is also low, the percentage is similar to the OECD average.

[5] The PISA 2009 questionnaire on ICT was voluntary; only four countries in the region participated: Chile, Panama, Trinidad and Tobago, and Uruguay.

Figure 4: Students aged 15 who use ICT in the home at least once a week, by type of use, 2012 (percentage)

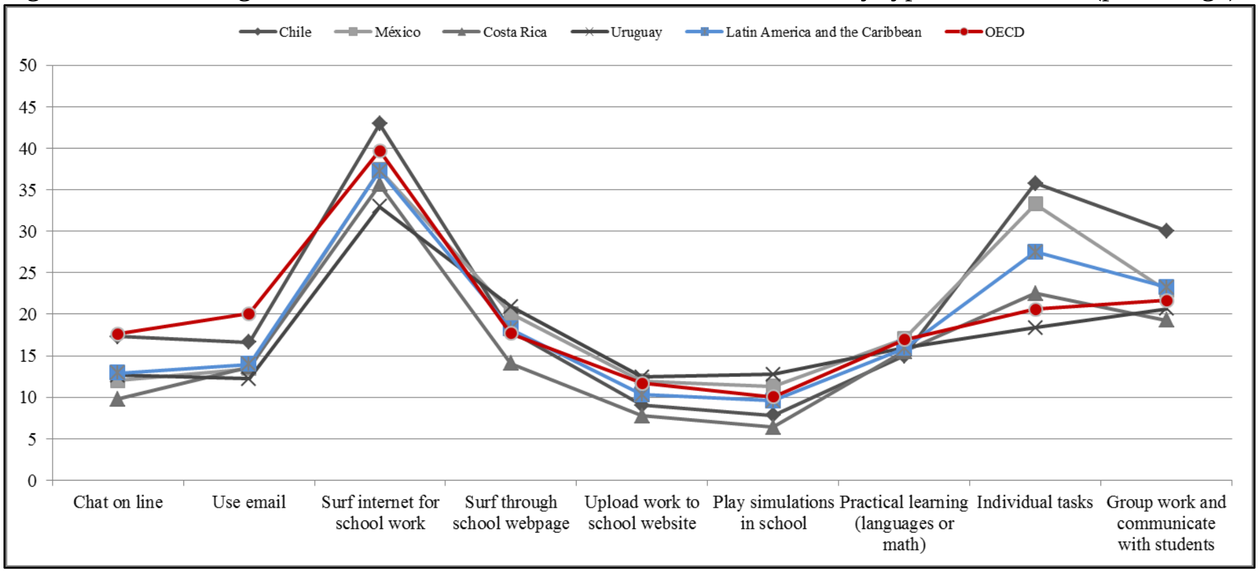


Source: Own calculations based on data from PISA 2012.

* The average for Latin America and the Caribbean is calculated only with the countries included in the chart.

Despite the significant increase in access to digital resources, the proportion of students engaging in ICT-related activities in school is markedly lower than any other activity with the computer at home, either recreational or for school work. The only exception is surfing the Internet for school work: between 30% and 45% of students reported doing this at least once a week, percentages similar to those reported for activities with computers at home (Chile reports the highest rate, even higher than the OECD average). Students also report using computers frequently for group work and to communicate with other students, especially in Chile and Mexico. These results indicate that providing connectivity to the schools could increase the use of these resources.

Figure 5: Students aged 15 who use ICT in school at least once a week, by type of use, 2012 (percentage)



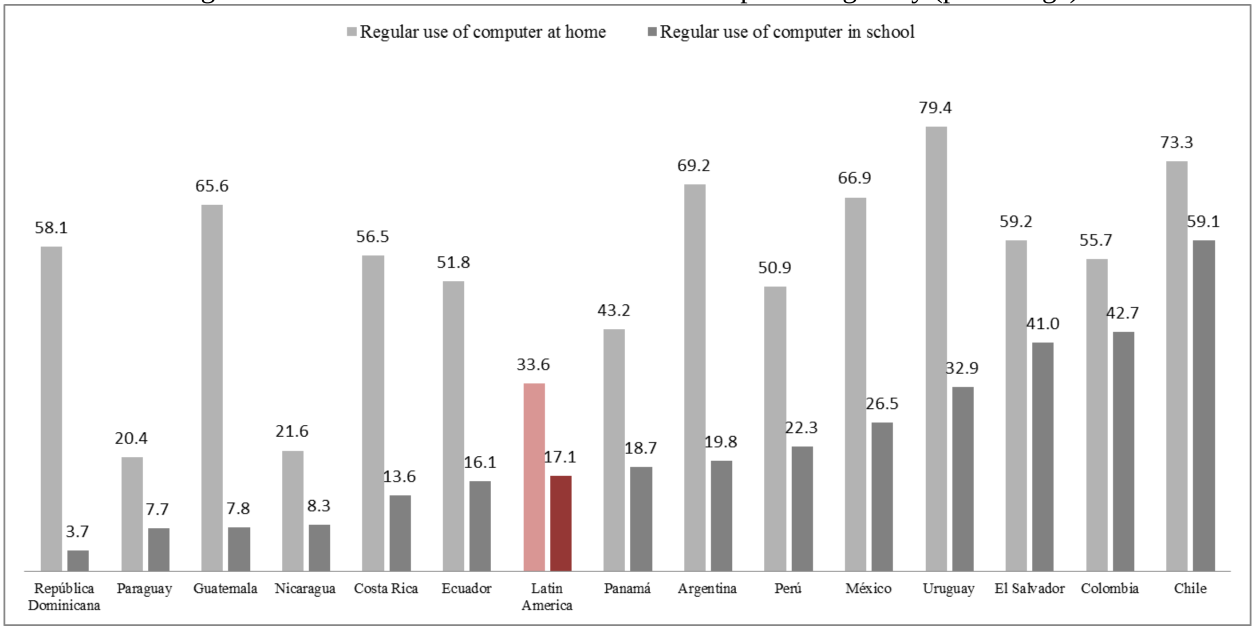
Source: Own calculations based on data from PISA 2012.

* The average for Latin America and the Caribbean is calculated only with the countries included in the chart.

How much do teachers use technology? Based on 2006 data from the Second Regional Comparative and Explanatory Study (SERCE), 34% of teachers said they used computers regularly at home and 17% at school. However, there is great variation between countries as shown in Figure 6. Teachers in Argentina, Chile, Colombia, Costa Rica and Uruguay use computers more than in other countries in the region. It seems that teachers are using computers more in countries with active education policies for ICT integration, such as Chile and Uruguay.

However, despite significant growth of programs to integrate technology into education in the region, teachers still make little use of computers. This could reflect the fact that this type of policy was adopted without investing the necessary resources or time needed to achieve acceptance by all the actors in the education sector, particularly teachers. Evidence suggests that they do not perceive the introduction of ICT in the sector just as the public authorities. In Honduras, a survey of teachers' perception of ICT executed as part of the Primary Education and Technological Integration Program revealed that, although they are convinced that the technology gives students access to better sources of information, 46% think students will use the computer mainly for playing (Luque, 2013). The perception is also negative regarding the impact of the introduction of technology to their work: about 40% believe computers increase their workload, reinforcing the idea that some policies that incorporate technology in the classroom need to provide teachers with sufficient resources, guidance and support for their proper use.

Figure 6: Latin American teachers who use computers regularly (percentage)



Source: SERCE (2006)

School management. Other promising uses of the new technologies for education relate to the collection, processing and dissemination of information on the education system and school management. The countries in LAC have implemented various types of management systems for educational information during the last few decades; for example, registration management systems based on identification, processing and dissemination of administrative information (students, teachers, school resources), statistics (indicators linked to education planning such as enrolment, dropouts, graduates), and evaluation (educational quality). Another example is management systems for geo-referenced information.

One recent initiative of integrated systems for information and administrative management in schools is the Computerization Program for High Performance in Costa Rica, introduced in 2011 to strengthen school administration in an effort to tackle low academic performance, absenteeism and the dropout rate. This system collects data from schools and generates aggregate reports on curricula, infrastructure and attendance. The program also aims to reduce teachers' heavy workloads by automating their routine reporting.

An interesting system for planning and analysis of student data is the platform DataWise developed by the NGO Measured Progress in the United States. DataWise uses students' results to help teachers and management teams adjust their teaching practices and improve performance. In Uruguay, the National Administration of Public Education in collaboration with Plan Ceibal, implemented a comprehensive online assessment system for school management, a pioneer in the region. The system evaluates students in the areas of reading, math and science from third to sixth grade. The results are positive, with high teacher satisfaction and sizeable lower costs compared with using paper-based tests (Fullan, Watson and Anderson, 2013).

III. A look ahead: New trends in technology in education

Technology is advancing rapidly and it is transforming different economic and social spheres. Since the mass adoption of computers, Internet and cell phones the pace of technological change has speeded up. Today the way we work, communicate and learn is subject to continuous processes of innovation and upgrading to incorporate the latest technological advances.

The education sector is not exempt from these processes. Schools and teachers are in direct contact with the younger generations, which have grown up with the new technologies. The advent of technology in everyday life has changed students' attitudes and expectations about learning. As a result, educational institutions, teachers and principals must change, modernize and adapt so students do not see schools as outdated, disconnected from their environment and unrelated to the challenges they face.

This section reviews global trends and presents some resources, innovations and uses of technology, which could change the educational process in the short to medium term. Describing these trends is important to consider potential possibilities and changes that may emerge in the educational landscape soon. It is also important to highlight that the principles and lines of action that the IDB follows in this area need to be flexible and continually updated.

Digital classrooms: computers, tablets and cell phones more and more present

The tablet explosion is one of the most important technology trends in education.[6] Large-scale initiatives have already been designed or implemented around the world, for example in India, Russia, Thailand and Turkey. Some countries, such as South Korea, even expect to completely eliminate textbooks in classrooms thanks to tablets in the next few years. In Latin America, more and more governments are implementing large-scale pilots or programs to introduce tablets into public schools. In Brazil the purchase of 5,000 tablets for distribution in public schools was put out for bidding in 2012.[7] Mexico invited technology companies to participate in the Digital Inclusion Pilot Program donating between 500 and 1000 tablets.[8] The new phase of the Ceibal Plan in Uruguay expects to deliver 5,000 tablets in 2014.

One of the biggest initiatives to date is the Tablets in Education program in Colombia. The program calls on municipalities and departments (provinces) to cofinance innovative projects that integrate the use of tablets into the education process and contribute to educational quality. The municipal authorities that submit a project have to have an educational partner such as universities, foundations or compensation funds with proven experience in education and training. The program is expected to benefit at least 1,000 schools and deliver about 300,000

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6 http://blogs.worldbank.org/edutech/some-more-trends.

7 http://www.telegrafo.com.ec/noticias/tecnologia/item/brasil-distribuira-tabletas-en-sus-escuelas-publicas-desde-el-2012.html.

8 http://www.reforma.com/libre/online07/preacceso/articulos/default.aspx?plazaconsulta=reforma&url=http://www.reforma.com/nacional/articulo/716/1431264/&urlredirect=http://www.reforma.com/nacional/articulo/716/1431264/

devices.[9] These are just a few examples. Other countries including Argentina, Chile, Jamaica and Nicaragua are also designing pilot programs with tablets.

Using cell phones for educational purposes is another trend. Smart phone penetration in Latin America is accelerating, offering students a variety of options for learning and interacting with the actors in the education process. According to figures published by the International Telecommunication Union in 2011, the average penetration of mobile-cellular telephones in Latin America and the Caribbean exceeded the threshold of 100%. In late 2011, 20 out of 33 countries in the region recorded more subscribers to mobile-cellular systems than inhabitants, including Argentina, Brazil, Chile, Ecuador, Guatemala, Panama, Peru and Uruguay. Although evidence of the effectiveness of these devices in education is still scant, pilot experiences in Afghanistan, Ghana and Uganda suggest that certain applications related to text messages can stimulate student motivation and participation in training programs for work (Raftree, 2013).

The price of technological devices continues to fall which, along with a growing number of suppliers, suggests that students in the region will have access to a great variety of devices. Given the growing popularity of tablets, computers will gradually move towards less traditional applications. This effect is confirmed by the emergence of new inexpensive minicomputers whose sales have increased dramatically in recent years. Some devices have the size of a credit card but can perform functions that vary from simple tasks such as word processing, video and audio to moving robots and creating intelligent homes. Their low price makes them especially attractive: some cost only US$25.

With this profusion of technological devices, bring-your-own-device programs are likely to become more popular. These programs have the advantage of not requiring investment in technological material because they maximize the use of the infrastructure already available in the community. But they have one major drawback: some case studies show that these programs involve significant risk of replicating socioeconomic gaps, given that children from disadvantaged homes often lack the equipment needed for participation (Raftree, 2013).

Connectivity and development of tools for communication, collaboration and peer learning

In Latin America and the Caribbean, Internet access still creates major challenges: it is slow and expensive compared with the OECD countries, and only 1 in 8 people have access to this technology (IDB, 2012). However, access to broadband is crucial for technology programs, and countries are investing heavily in infrastructure to bring broadband to all their territory. This is why the IDB launched the Broadband Initiative, which allocates significant resources to expanding high speed across the region. This initiative gathers the coordinated work of different technical teams of the IDB and is expected to contribute to the project "20, 20, 20" of the International Telecommunication Union: 20 mega broadband Internet for US$20 by 2020 across the region.

[9] http://www.mineducacion.gov.co/cvn/1665/w3-article-323727.html

Widespread access to broadband has a transformative impact on the design of innovative teaching and school management programs. The incorporation of streaming video, communication and real-time teleconferencing creates a universe of new ways of learning, with access to experts not available locally.[10] The dissemination of information and open source transcend the physical silos of school and classroom. One example of this trend is the Khan Academy, which has produced about 2,400 free videos watched by 10 million students monthly. This type of tool has broad potential, and in the next few years the number and type of platforms could increase.

Along these lines, in Latin America there are important initiatives, such as the Tareas Plus tutorials channel, developed by two young Colombians. This large library of virtual courses is now the largest educational platform in Spanish. Given the lack of materials and original content in Spanish and Portuguese, or even translated, there is plenty of room for such initiatives to expand in the near future. The Bank can play an important role in promoting and supporting development of information platforms, online courses and tutorials for countries in the region.

Mass online open courses (MOOC) have been enthusiastically received, and an increasing number of higher education institutions are offering them. Even the most selective institutions, such as Harvard, believe that educational technology has enormous potential for improving teaching and learning.[11] One sign of the growing importance of online courses and materials is that the European Union has focused its educational technology strategy on an education portal launched in September 2013. The purpose of this website is to present to students, teachers and researchers a variety of open educational resources in different languages, such as MOOC, communication tools for students and teachers, and high-level research articles on the use of educational technology and applications.

Access to computer material and connectivity also offers opportunities for new tools for collaboration, learning and feedback among teachers. On one side are the platforms or learning networks where teachers can learn from other teachers, improve their skills and deepen teaching practices through online tutorials, such as the ”Docente al Día” platform in Chile.

However, one of the most promising trends relates to classroom observation and teacher training. The effectiveness of the teacher is the most influential factor in student learning, and technology provides systems that offer continuous and personalized feedback to teachers. The logic is not to invest only in "perfect teachers" but to develop tools and models, which enable teachers to collaborate and improve their practices by interacting with each another, or with a coach who gives comments and advice directly. Constant practice and feedback can lead to improvement. An example is the Iris LiveView system which, with only one camera in the classroom, a computer and an Internet connection, allows an instructional coach to see and hear what is

[10] The emergence of this type of project is reflected in the latest lending operations approved by the Bank and in operations in preparation, such as those in Brazil or the second phase of Uruguay’s Ceibal Plan described below (see section V).

[11] http://harvardmagazine.com/2013/09/harvard-past-president-endorses-online-education.

happening in the class, from anywhere in the world. The installation costs are about US$500 (for the fixed camera model, the portable version costs US$3,500), and the system allows a 360-degree viewing angle with two cameras. The second camera has microphones for teachers and students, and a portable handset for the teacher who can receive remote instructions.[12]

Innovations in what is taught: 21st century skills

Technology is changing the labor market. In the United States, jobs in occupations that involve performing routine tasks, such as bank tellers and travel agents, are shrinking (Author and Dorn, 2013). This trend could accelerate in the coming decades due to technological innovations related to the use of “big data” and the lower cost and associated increase in use of applications capable of automating processes (Frey and Osborne, 2013).Technological changes are transforming the skills demanded from workers. Encyclopedic knowledge in areas such as geography or history is less useful in an era when this information can be obtained immediately and at marginal cost. Many experts argue that skills such as creativity, critical thinking, communication and collaboration will become more important, and that the education system must change to support their development. Although these skills need to be stimulated, even proponents of this shift in emphasis, such as the Partnership for 21st Century Skills, argue that knowledge and skills of certain traditional subjects has to be maintained. These include language, foreign languages, art, math, economics, science, geography and citizenship.

These changes in the labor market will require a detailed analysis of the curriculum of educational systems to adapt them to these new trends. However, these changes will require a series of reforms in line with the existing situation in each country or region. Latin America has poor results in international comparison tests in subjects such as math, language and science. And students with low socioeconomic level or living in rural areas get even lower results. Thus, although the curriculum has to be adapted to new trends, sustained efforts are needed to ensure that all students in our region develop basic skills in critical areas such as math and language.

Innovations in how to teach: a constructivist model

In recent decades a "constructivist" educational stream has emerged, whose foundation is that knowledge must be constructed, and the simple transmission of knowledge should be avoided. Constructivism proposes that educational activities are relevant and useful from the child’s perspective, and encourages collaborative work and the role of the student in defining their educational process (Hernández, 2008). Some experts argue that technology can play an important role in implementing this approach in teaching practices in the classroom. By giving access to a large volume of resources and allowing easier collaboration and communication among students, technology could facilitate the implementation of constructivist practices.

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[12] See www.therenow.net.

Some governments in the region are proposing changes in teaching methods to introduce practices closer to constructivist models and they are analyzing ways of using technology to support these reforms. However, evidence on the effectiveness of constructivist-type activities is inconclusive. Moreover, there is no consensus on the feasibility of this type of educational models for our region in the near future. As a result, it is important to document promising initiatives that demonstrate the feasibility of this educational model in the field. This would be a sensible first step prior to evaluating this teaching model and promoting its large-scale adoption.

Innovation in how innovation is promoted

Though these trends are promising, there is still a process ahead for technology to make really innovative changes. For this reason, the Office of Educational Technology of the U.S. Department of Education is promoting regional innovation clusters among schools, researchers and the industry, with the expectation that these partnerships will speed up development of new tools and approaches to learning and lead to their adoption on a large scale.[13] In this view, educational technology has not had the desired transformative effect because research into the science of learning is disconnected from practical implementation, whereas the research, product, development and adoption should be linked together in the "educational innovation ecosystem." In the digital age, lack of appropriate technological infrastructure prevents development and adoption of new approaches on how to teach and use the information in class.

Something similar is taking place, although on a smaller scale, in Latin America, for example, with Colombia's Smart School initiative. This project aims to create digital classrooms for academic research to identify new and better teaching practices based on use of technology in classrooms. Smart School also involves a complete "ecosystem" consisting of actors from the technological, educational and research fields, to generate knowledge on teaching and learning through tablets and specialized learning applications. Currently, the project aims to identify comprehensive strategies to improve student performance in math, science and reading comprehension.

[13] http://www.ed.gov/edblogs/technology/innovation-clusters.

IV. Empirical evidence

Studies analyzed

In this section we review the evidence on the impact of technology programs that aim to raise student learning through improving instruction. We analyze the evidence to determine average program impacts, how the effects vary by program types, how these effects compare with other educational interventions and how much programs typically cost. We apply strict criteria to identify studies with high methodological rigor, relevant for Latin America and the Caribbean (LAC). In particular, we select studies with experimental evaluations on a large scale in developing countries.

There is a consensus that large-scale experimental evaluations provide the strongest evidence for determining program impacts. However, the estimated effect can depend on the context. This implies that the results obtained in a specific context (for example, rural Peru) may not necessarily be directly extrapolated to other environments. Still, if the evidence suggests that certain programs tend to generate similar impacts in different regions of the world, then the findings will be more generalizable.

While a decade ago there were no large-scale experimental evaluations of technology in education, in recent years a great deal of evidence has accumulated. Table 2 lists the 15 experiments identified during the literature review. The top panel presents 11 experiments of programs, and the lower panel shows four studies of programs that do not guide the use of technology.[14] In total, about 47,000 students in 1,200 schools participated in these evaluations.

With respect to infrastructure and place of use, seven experiments involved the use of computer labs and in five the equipment was used in the classrooms. In two experiments personal laptops were provided for students to use at home, while in one program students received personal laptops for use at school and at home. The studies focused on primary level, except a study that included students through third to ninth grade. Of the subjects targeted in each experiment, six were aimed at improving learning in mathematics, five in language, two in both subjects while two did not specify which subject was targeted. Finally, the programs were grouped regionally in India, China and Latin America (six, five and four experiments, respectively).

[14] In general, each study analyzed reported the results of an experiment, with the exception of Linden (2008) and He, Linden and MacLeod (2008) who reported two and three experiments, respectively. In these cases, we use Roman numerals to identify the experiments. For example, we reference as Linden (2008-i) the first experiment reported by Linden (2008) and Linden (2008-ii) the second experiment presented in the mentioned study.

Table 2: Studies analyzed

Experiment	Guided use	Infrastructure and place	Grade	Focused area	Country
Lai et al. (2011)	Y	Computer lab	3	Math	China
Lai et al. (2012b)	Y	Computer lab	3, 5	Math	China
Mo et al. (2013)	Y	Computer lab	3, 5	Math	China
Lai et al. (2012a)	Y	Computer lab	3	Language	China
Banerjee et al. (2007)	Y	Computer lab	4	Math	India
Carrillo et al. (2010)	Y	Computer lab	5	Math + language	Ecuador
He et al. (2008-i)	Y	Equipment in classroom	2-3	Language	India
He et al. (2008-ii)	Y	Equipment in classroom	2-3	Language	India
He et al. (2008-iii)	Y	Equipment in classroom	2-3	Language	India
Linden (2008-i)	Y	Equipment in classroom	2-3	Math	India
Linden (2008-ii)	Y	Equipment in classroom	2-3	Math	India
Barrera-Osorio y Linden (2009)	N	Computer lab	3-11	Language	Colombia
Cristia et al. (2012)	N	Laptops home and school	2-6	-	Peru
Beuermann et al. (2013)	N	Laptops home	3-6	-	Peru
Mo et al. (2012)	N	Laptops home	3	Math + language	China

Next we briefly describe these experiments. Four guided programs used computer labs in China (Lai et al, 2011, 2012 and 2013; Mo et al, 2013). In these programs, students used adaptive software for two weekly 40-minute sessions. In each session, students watched a video on the concepts covered in regular classes and then did exercises on the computer. The session coordinators had to ensure that the topics were covered at the same time as they were covered in regular classes, and could not provide instruction on the content. The coordinators received a two-day training course and visits from voluntary supervisors who found a high level of fidelity with the program design. Three of the programs focused on math and one on language. Three programs were developed in rural areas although one was implemented in schools in Beijing attended by migrants from rural areas. Lastly, in three of the experiments the sessions were held outside school hours, and in one the sessions took place instead of regular computer classes.

Two other guided programs involved computer labs. Banerjee, Cole, Duflo and Linden (2007) analyzed a program to improve performance in math using computers for two hours per week, one hour during the school day and the other before or after school. In the sessions students played games that involved solving mathematical problems whose difficulty was adapted to the level of the students. The session coordinators came from the communities and received a five-day training course. The coordinators had to stimulate students to use games that challenged their existing skills and, if necessary, help them to understand the planned activities, but could not provide instruction in math. Carrillo, Onofa and Ponce (2010) evaluated an intervention in Ecuador in which fifth graders used adaptive software for three hours per week to learn math and language. Two teachers and one principal from each participating school were trained for the adaptive software provided.

Five experiments involved using technology in regular classrooms. Three were aimed at improving English competence of second and third graders in India by using a portable device called PicTalk (He, Linden and MacLeod, 2008). Using this device, students choose pictures on sheets placed in the device and then listen to the English pronunciation of the associated words.

The device also includes exercises in which students have to point to certain words to get the correct auditory response. In two of the experiments the intervention also used worksheets designed to cover the same concepts as the PicTalk device (in the third only the device was used). Students had to use the electronic devices and worksheets on alternate days. In one of these experiments, the staff of a local NGO implemented the intervention, while for the other two experiments, regular teachers were in charge.

The other two guided-use programs that use computers in the classroom aimed to improve students' math learning (Linden, 2008). Students had to use the computer for one hour daily. In one program, students spent one of the three hours of daily class time using the computer. In the other program, the daily hour of computer use was for additional instruction outside school hours. Two students shared a computer and the screen was divided so the exercises could be done independently. The exercises had to relate to regular class topics, and were not adapted to the level of the students. The teachers were responsible for the logistics and the times assigned to each student.

The guided-use programs described present certain common features. First, the interventions focus on using computers in school, which is logical considering that it would be difficult for program implementers to supervise computer use in homes. Second, students share computers and equipment. Third, the programs include students in one or two grades; this could be due to the intention to align the software, planned activities and curriculum objective. Fourth, the programs aim to develop academic skills: 10 of the 11 cases involve a single subject. Fifth, instruction with computers is supplementary, that is, it does not intentionally change teaching practices in regular classrooms. Sixth, computer use is aimed at practical exercises and not to freer use or search for information. Seventh, the programs are concentrated regionally in India and China. Eighth, the role of the instructor in charge of the sessions is usually to solve logistical problems and clear up doubts about the software, but they are not supposed to give instructions to students on the target subject.

The characteristics of the four unguided-use programs are more varied. The program evaluated by Barrera-Osorio and Linden (2009) consisted of delivering 15 computers to schools, but there is little information on how these additional resources were expected to be used. This was revealed in the evaluation that documented increased computer use in the technology class, but not for math and language. The OLPC program in Peru provided personal laptops to students and teachers for use at school and at home (Cristia et al., 2012). Surveys to students and teachers, records of computer logs and a parallel qualitative evaluation documented limited use of computers in activities that could impact learning in math and language.

The other two nonguided programs distributed laptops for exclusive use at home. Beuermann et al. (201 3) evaluated an OLPC pilot program for primary students which trained the beneficiary students to use the applications provided in seven weekly sessions of two hours. The applications installed in the computers were selected by the Peruvian government for its national program and included nearly 200 digital books (although it did not include adaptive software aligned to the curriculum). Perhaps the pilot evaluated by Mo et al. (2012) in China is the program that most clearly attempted to direct the use of personal laptops to developing academic skills. The team that implemented the project installed interactive software on the laptops adapted to the level of study and aligned with curriculum objectives in math and language for third grade. During the session of delivery of the laptops, the beneficiary students and their parents received training in the software. The evaluation documented a limited impact on computer use for school-related activities.

Impact on academic skills

Table 3 presents the evidence of program impacts on academic skills, expressed in standard deviations.[15] The results suggest a positive impact in both math and language. In 14 of the 15 experiments analyzed the effect on learning in math was positive (in 9 cases significant) and in 1 study the effects were negative and significant. In language, 12 studies found positive effects (significant in 4 cases), 2 reported not significant negative effects, and 1 study did not report results in this subject. The impact on the average score in math and language was positive in 13 cases (significant in 7 cases), in 1 case significant negative and in 1 case could not be calculated.[16]

Table 3: Impacts on academic skills: individual studies

Experiment	Guided use	Average	Math	Language
Lai et al. (2011)	Y	0.08*	0.14**	0.01
Lai et al. (2012b)	Y	-	0.12**	-
Mo et al. (2013)	Y	0.11*	0.16**	0.05
Lai et al. (2012a)	Y	0.21**	0.22**	0.20**
Banerjee et al. (2007)	Y	0.21**	0.35**	0.01
Carrillo et al. (2010)	Y	0.27	0.37*	0.16
He et al. (2008-i)	Y	0.26**	0.05	0.28**
He et al. (2008-ii)	Y	0.37**	0.35**	0.28**
He et al. (2008-iii)	Y	0.37**	0.39**	0.33**
Linden (2008-i)	Y	-0.48**	-0.57**	-0.28
Linden (2008-ii)	Y	0.25	0.28	0.18
Barrera-Osorio and Linden (2009)	N	0.08	0.09	0.08
Cristia et al. (2012)	N	0.00	0.05	-0.04
Beuermann et al. (2013)	N	0.07	0.06	0.07
Mo et al. (2012)	N	0.09	0.17*	0.01

Note: * and ** indicate statistically significant impacts at 10% and 5%, respectively.

[15] This is the traditional way of measuring impacts on learning. It is calculated as the mean difference in the test scores between students in the treatment and control groups, divided by the standard deviation of scores in the control group. Third graders in the United States increase their test scores by about 0.4 standard deviations in one year.

[16] Seven studies did not report any impact on the math and language average. In these cases this value was imputed as the average of the estimated impact reported for both subjects. The same procedure was applied to impute the standard error of the average impact.

To aggregate the estimated impacts and compute average effects, we apply meta-analytic techniques. This methodology allows quantitative reviews of the literature by aggregating the results from a variety of studies. Basically, weighted averages of the estimates of the studies are calculated, giving more weight to studies with greater statistical accuracy.[17]

Table 4 reports the main results of this analysis.[18] In general, the reviewed programs had a significant positive impact of 0.13 standard deviations on the average score in math and language. This important result suggests that the evaluated programs have produced, on average, a sizeable improvement in student learning. A breakdown by subject shows that the interventions analyzed had a significant positive impact of 0.16 standard deviations in math, and 0.11 in language.

Table 4: Impact on academic skills: Meta-analysis

Panel A: All the studies			
	Average	**Math**	**Language**
	0.13**	0.16**	0.11**
Panel B: By type of program			
Guided use	**Average**	**Math**	**Language**
Y	0.17**	0.18**	0.15**
N	0.04	0.07*	0.02

Note: * and ** indicate statistically significant impacts at 10% and 5%, respectively.

The lower panel of the table reports results on a crucial aspect. What type of program has generated most benefits? Guided-use programs have a significant positive impact of 0.17 standard deviations, against a (non-significant) effect of 0.04 for nonguided-use programs. This means that programs that guide use have produced learning benefits four times greater in academic skills than those that do not guide it. This greater impact of guided-use programs is consistent with the limited use of computers in academic activities found in nonguided-use programs. For example, the evaluation of the program that distributed computers to schools in Colombia documented that there were no increases in the use of technology for math and language (Barrera-Osorio and Linden, 2009). Similarly, the evaluation of the OLPC program in Peru found limited use for improving learning in math and language (Cristia et al., 2012).

Guided-use programs tend to generate a higher average impact but also greater dispersion of impacts. The estimated average impacts for guided-use programs ranges from -0.48 to 0.37 against a range of only 0.00 to 0.09 for programs that do not guide use. Since this range may be

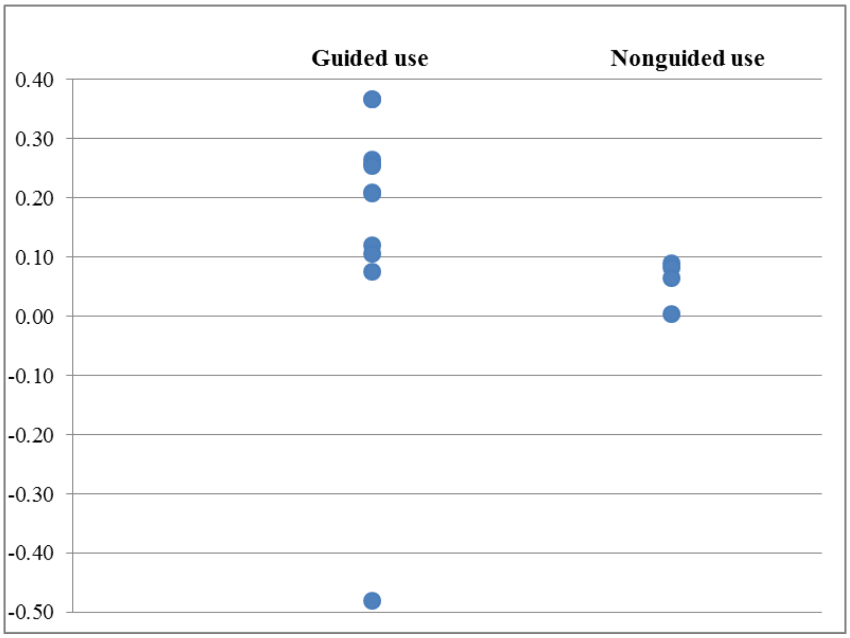
[17] For this meta-analysis, random effect models are estimated assuming that the estimated impacts were correlated at the study level (Ringquist, 2013). To make a consistent comparison of the impacts found with those identified in other educational interventions, we apply a methodology similar to McEwan (2013); that is, we calculate effects on math and language with one observation per experiment, collection round and area measured. We then multiply the weights of each study to add the impacts using random effect models using a weight of $1/n_{i,}$ where n_i is the number of estimates codified in the study *i*.

[18] Part of the results presented in this section are from a meta-analysis by Berlinski, Busso and Cristia (2013).

influenced by the number of studies in each group, we examined a more robust dispersion measure. Analyzing the standard deviation of the estimated impact by programs we came to the same conclusion: the standard deviation of the estimated impacts of guided-use programs is 0.23 compared with 0.04 for nonguided. Excluding the experiment of Linden (2008-ii), which reports a high negative effect, the standard deviation of guided-use programs is still higher (0.10).

Figure 7 shows the impacts of the two program types on academic performance. Each dot corresponds to the average impact on math and language of one program. The chart shows that guided-use programs tend to generate higher returns in terms of learning, but also larger dispersion.

Figure 7: Impact on average academic performance by study



Do other characteristics predict the impact of a technology program? It could be that programs with longer duration generate greater impacts. It could also be that programs that involve the use of computers outside school hours are more effective than those that use computers only during school hours. This could be because the former increase the overall time spent on educational activities. To explore these hypotheses, we ran regressions where the dependent variable is the program's impact and we added different explanatory variables. First, we analyzed whether the impact was different when we grouped the programs according to the following design variables: use only at school, program duration at least one year, training of instructors for three days or more.

Second, we analyzed whether there were differences according to the following context and implementation variables: region (indicators for India and China, respectively, with Latin America as the reference category); government implementation (implementation by NGOs or researchers as the reference category); average student grade included lower than fourth grade; number of schools included in the study (to analyze whether larger scale interventions have lower impacts); and number of students included in the study.

Due to the low number of observations (there are only 34 coefficients reported in 15 experiments) we ran regressions where we included only one of the categories of variables described as explanatory variables in each specification. The results show that none of the variables analyzed, except the guided or nonguided indicator, are significantly correlated with the reported impacts (see Annex I). Neither the program design variables, such as program duration over one year, nor those related to context and implementation, such as the region where the program was implemented, predict the observed impact. Although the analysis suggests that these characteristics do not appear to have a significant effect on the observed impacts, it is important to note that this analysis has methodological limitations. In particular, each comparison contrasts the results of programs that differ in the dimension analyzed (for example, duration) but also in other dimensions.

To explore the robustness of the greater impact found for guided-use program, we ran regressions of the program's impact on an indicator for guided use and controlling for the variables described in the previous analysis (for example, use only at school, program duration). The positive and significant differential for guided-use programs of about 0.11 standard deviations is robust to including these controls. The estimated differential varies between 0.09 and 0.13 depending on the controls included, and is always statistically significant (see Annex II). It is also important to note that these two groups of programs (guided use as opposed to nonguided use) differ by a group of dimensions which are typically correlated with the type of program. For example, most guided-use programs increased the time spent on the targeted subject (math or language) unlike the unguided-use programs. However, it is important to recognize that the increased time spent on the focused subject in the guided-use programs was typically limited (for example, 80 minutes weekly in the studies of Lai et al, 2011; Lai et al, 2012; and Lai et al., 2013).

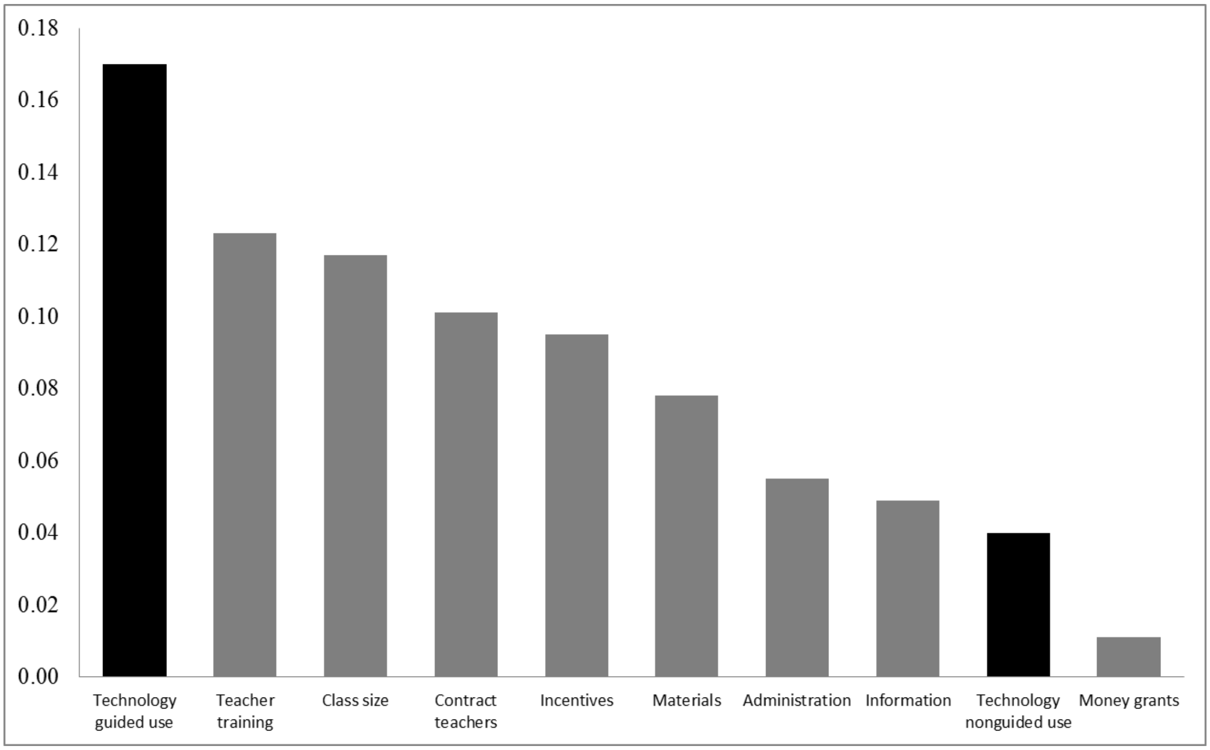
While it is important to provide evidence on the effects of different technology in education programs, it is also useful to analyze how these effects compare with other educational interventions. To explore this aspect, we combined the results of the average impact by type of program with the results from a recent meta-analysis (McEwan, 2013). In this study the results of 76 large-scale experiments conducted in developing countries measuring impacts on academic performance were coded. Since we followed the same methodology in our study, the results should be comparable.

Figure 8 presents the average estimated impacts in our analysis (black bars), compared with the average impacts of other educational interventions from McEwan (2013) (gray bars).[19] Of the 10

[19] McEwan (2013) also includes average impacts of health and deworming interventions. Because these programs are not directly aimed at improving educational results, we do not include them here. The average impact of

types of educational programs analyzed, the technology programs that guide use are the most effective. The nonguided-use programs are among the least effective, performing only better than the programs that provide money to school committees and teachers to purchase educational materials. However, these comparisons must be approached with caution, since the programs compared may have different costs, contexts and quality of implementation.

Figure 8: Impact on average academic performance by type of educational program



We now summarize the main findings. First, technology in education programs tend to improve student learning. Second, programs that guide use produced increases in learning substantially greater than those focused on providing resources. Third, guided-use programs seem to generate more dispersed impact than nonguided-use programs. This dispersion suggests high returns from experimenting with different models of guided-use programs to identify the most effective ones. Fourth, the evidence suggests larger impacts on math compared with language. Fifth, guided-use programs are among the educational programs with the highest impacts on academic performance, while nonguided-use programs are among the least effective.

Finally, it is important to recognize that the bulk of the evidence on the high effectiveness of programs that guide use comes from India and China, while the evidence on the impact of nonguided programs comes from studies in Latin America. Also, the analysis compares

technology programs in our study is slightly lower because we also included, unlike McEwan (2013), the results reported by Beuermann et al. (2013).

programs that differ in a variety of sizes and in different contexts. This suggests caution in interpreting the results. However, the strong evidence accumulated suggests that, at least in our region, implementation of nonguided-use models yields only modest returns. The promising results of guided-use programs in India and China suggest that these programs may be effective in Latin America. Experimenting with guided-use models in Latin America and the Caribbean can have high returns. Yet, experimentation should be the first step before implementing this type of programs on a large scale.

Impact on digital, general, cognitive and socio-emotional skills

This subsection presents the existing high-quality evidence of the effects of technology in education programs on digital and general cognitive skills, self-concept and motivation. Unlike academic performance, measured by all the evaluations analyzed, only a few studies report effects in these areas. Consequently, the evidence in Table 5 should be considered tentative.

Table 5: Impact on digital, general cognitive and socio-emotional skills

Study	Guided use	Digital	General cognitive	Self-concept	Motivation
Panel A: Studies					
Lai et al. (2011)	Y	-	-	0.07*	0.16**
Lai et al. (2012a)	Y	-	-	0.02	-
Cristia et al. (2012)	N	-	0.11*	-0.13**	-0.09
Beuermann et al. (2013)	N	0.88**	0.05	-	-
Mo et al. (2012)	N	0.33**	-	0.12**	-
Panel B: Aggregated impact					
	Guided use	**Digital**	**General cognitive**	**Self-concept**	**Motivation**
	Y	-	-	0.05*	0.16**
	N	0.61**	0.07**	0.00	-0.09

Note: * and ** indicate statistically significant impacts at 10% and 5%, respectively.

The lack of evidence about effects on these areas is especially acute in the case of guided use programs. In none of these experiments the effects on digital skills or general cognitive skills were measured. Only two studies measured effects on self-concept and one study measured impact on attitudes to school. Evidence suggests modest positive effects on these socio-emotional areas. The fact that few evaluations of guided-use interventions measure effects on these areas could be explained by the strong motivation on raising academic achievement underlying these programs.

The evaluations of nonguided-use programs provide more information on impacts in these areas, and show robust positive results on development of digital skills. Mo et al. (2012) reported significant positive effects of about 0.33 standard deviations, while Beuermann et al. (2013) found a positive effect of 0.88 standard deviations. This greater impact could be due to the intensive training provided to students focused on these skills. Alternatively, this difference could occur because the laptops provided in Beuermann et al. (2013) contain the specialized Sugar environment software, which has been specifically designed for educational use by primary school students, and measurement of the evaluation was focused on these skills. The estimated average impact on these areas is 0.61 standard deviations.

With respect to the effects of these programs on cognitive skills, the evidence suggests a positive and significant impact, albeit modest (0.07 standard deviations). Both the evaluation of OLPC program in rural Peru and the pilot for delivery of personal laptops for use at home reported positive effects, although significant only in the first case (Cristia et al, 2012; Beuermann et al., 2013). The evidence for effects on socio-emotional skills of the nonguided-use programs seems to indicate limited effects in these areas. In the case of self-concept, Cristia et al. (2012) reported negative and statistically significant effects of 0.13 whereas Mo et al. (2012) found a positive statistically and significant effect of 0.12. For motivation measures, there is only evidence from Cristia et al. (2012) who reported a negative not significant effect of 0.09.

Some studies analyzed effects on variables related to enrollment and attending school. Nine studies measured what percentage of students surveyed at baseline were surveyed at follow up. This attrition indicator is influenced by dropouts and attendance. There were also three studies that examined effects on attendance. The average effects on attrition and attendance, estimated again using meta-analytic techniques, were not statistically significant. The effects, measured in standard deviations, were 0.00 for attrition and 0.00 for attendance. This evidence strongly suggests that technology in education programs have an extremely limited impact on decisions related to enrollment and attendance. Lastly, none of the identified studies analyzed the impacts on the 21st century competences described in Section I (creativity, critical thinking, communication, collaboration).

Although there are a number of knowledge gaps in this area, three research questions were identified whose answers could have important implications for public policy decisions in the sector. First, the high returns on academic performance from guided-use programs found in other regions of the world. Could they be replicated in the LAC context? Second, how can the impact of these programs be increased? For example, none of the studies considered the advantages offered by Internet access in educational environments. Given the education potential offered by having access to Internet, the interest of countries in the region in this area and the IDB Broadband Initiative, a solid analytical work to guide policy decisions in this area is essential. Third, in recent years low-cost tablets have entered the market which could greatly reduce the required investments in educational technology programs. Could the use of tablets generate high educational impacts at low cost? These innovations on the hardware side are accompanied by an explosion in the number of educational applications available. Since these trends are recent there is yet no evidence on their possible impact and how it could be maximized, consequently the analytical work in the area could increase expected returns on the investments in the sector.

Costs

What are the costs of technology in education programs? We present here the evidence reported in the studies analyzed above, complemented by the calculations from Berlinski, Busso, Cristia and Severín (2011) on the cost of various technology in education programs in Latin America. We conclude with a brief discussion on the cost structure of these programs. However, it is important to recognize that the costs reported relate to information collected in the past. Because the costs of technological devices tend to fall over time, the findings of this subsection should be considered with caution. Policy decisions should be based on a prior analysis of the expected costs when implementing a specific technology in education program.

In general, the studies reviewed contain scant information on costs. As shown in Table 6, three studies reported the total annual cost per student. Banerjee, Cole, Duflo and Linden (2007) reported a cost of US$15 per student per year for the program in which fourth graders used computers for two hours per week in India. Linden (2008-ii) reported that the program that provided one daily hour of computer use for math learning for second and third graders in India, cost of US$8 per student per year. The low cost of this program could be explained in part by the purchase of used computers reconditioned for use in schools. Finally, He, Linden and MacLeod (2008) report a similar cost, US$8 per year per student, for the program evaluated which provided electronic devices for learning English to second and third graders.

Table 6: Costs

Study	Country	Guided use	Cost	Information reported
Banerjee et al. (2007)	India	Y	15.2	Annual cost per student
Linden (2008-ii)	India	Y	8.7	Annual cost per student (plus electricity)
He et al. (2008-ii)	India	Y	8.5	Annual cost per student
Cristia et al. (2012)	Peru	N	188	Cost per laptop delivered
Beuermann et al. (2013)	Peru	N	188	Cost per laptop delivered

Note: Costs are presented in US$.

Two evaluations of nonguided-use programs report infrastructure costs. Cristia et al. (2012) and Beuermann et al. (2013) evaluated the OLPC program, for which the Peruvian government purchased laptops at US$188 each. Although these figures are not directly comparable with the earlier ones because they do not include all the costs (and the cost of infrastructure also has to be prorated over time) they do suggest that programs that provide laptops for personal use tend to cost markedly more.

Berlinski, Busso, Cristia and Severín (2011) report the cost of three technology in education models in LAC. The first, at US$23 per student per year, involves the use by students of computer labs for two hours per week, using free content and with limited teacher training. The second model, at US$94 per student per year, provides students with personal laptops, free content and limited training for teachers. The third model, at US$217 per student per year, includes provision of personal laptops for students, content development and intensive training, supplemented by regular visits by supervisors.

How do the costs of guided and nonguided programs compare? The costs of technology in education programs are based on three key components: infrastructure, content and human resources, and are not directly linked to whether the program guides or does not guide the use of the technology. However, the evidence presented suggests that guided-use programs that provide students two hours of weekly computer use tend to have low costs. For example, the costs of the program that provided two hours of weekly use to improve learning in math for fourth graders had a cost of US$15 per student per year (Banerjee, Cole, Duflo and Linden, (2007).

The low cost of guided-use programs can be explained by the intense use of the technological resources that these initiatives allow. With guided-use programs, the time that computers and Internet will be used can be planned, so the percentage of time that computers are used can approximate 80%, that is, close to full utilization. With respect to content, since the software to be used is determined in the design stage, it is not necessary to produce a great variety of resources for different purposes and uses, hence the provided content can be used intensively. Guided-use programs also require substantially less training for teachers or other personnel that coordinate the technology session. This is due to the fact that these coordinators only need training in the specific software to be used, which reduces training costs and allows coordinators to make intensive use of the knowledge acquired. Finally, it is important to recognize that programs that initially aimed at expanding access to technological resources can implement complementary actions to guide use; this would require an additional limited investment and could markedly increase their effectiveness.

An important aspect of the total cost of a program is how it varies in relation to scale. Certain costs are variable and will grow almost linearly with the scale of the program. The cost of providing infrastructure has this feature. For example, a program that delivers 200 laptops will spend about twice as much on equipment as a program that delivers 100. Likewise, the cost of training teachers might be expected to grow linearly with the scale of the program. By contrast, the cost of producing content is fixed. Once software has been developed, the extra cost of an additional copy for student use is negligible. The cost of designing guided programs is also fixed and independent of the scale of the program. This is because identifying an effective model for teaching certain subject requires investing in activities that do not depend on the number of beneficiary students.

These characteristics of the cost structure have two policy implications. First, small-scale programs should concentrate on providing infrastructure and on training teachers, adopting free content and promising solutions from other contexts. By contrast, for large-scale programs (for example, national programs) it would be efficient to invest in developing content and producing effective solutions, since the resulting products (software and effective solutions) will improve the expected results for a large number of beneficiaries.

Second, both content and development of effective solutions are public goods. Consequently the IDB could play an important role since the software and knowledge created could be shared with the countries of the region. The IDB could promote creation of these products and coordinate activities among the countries in the region. As described in Section V, the IDB has successfully played this role in the past. Due to the work of the IDB in this area, LAC countries are strongly represented in the meta-analysis performed. Three of the studies in our region have been funded by the Bank, while the remainder evaluation was supported by the World Bank.

We will now summarize the most important points on the costs of technology in education programs. First, there is high level of variation on program costs, it can range from US$10 to over US$200 per student per year. Second, the key to reducing costs and increasing the efficiency of programs is to use the technological resources provided as intensively as possible. Third, guided-use programs that target a specific area require a limited investment. This lower cost is typically achieved because students share computers, content is provided only on the focused learning objectives, and staff is trained on the specific tasks needed for effective implementation of the program. Lastly, the fact that software and knowledge about effective models are regional public goods that can benefit all the countries in the region is a solid foundation for the IDB involvement in these areas.

V. Technology in education programs supported by the IDB in the region

This section synthesizes the IDB support to technology in education programs in the region during 1998 to 2013. It describes both the operational work executed through loans and the analytical work implemented through Technical Cooperations and Economic and Sectoral Work studies. This information is summarized in Table 7.

Table 7: IDB Contribution to technology in education programs in the region

Instrument	Total investment (US$ million)	Objective
Loan operations (11 projects)	1,202.5 (187.7 ICT components only)	Infrastructure: - Computer labs, multimedia rooms (US$119.8 million in Bahamas, Barbados, El Salvador, Guyana, Jamaica, Trinidad and Tobago) - Mobile labs (US$23.8 million in Argentina) - One-to-one models (US$23.1 million in Honduras and Uruguay)
		Increased coverage (US$19.5 million in Pará and Amazonas states, Brazil)
Knowledge products (27 projects)	15.7	Implementation of pilot programs and operational support (Colombia, Costa Rica, Haiti, Honduras, Paraguay, Uruguay)
		Content development: creation of RELPE, personalized learning models (Chile), use of video lessons and digital resources (Brazil)
		Impact and process assessments and evaluation methodologies: impact evaluations (Peru and Brazil), process evaluations, comparative studies of technology use in the classroom and methodology studies
		Dissemination and knowledge sharing: identification of best practices action framework, analysis of experiences and regional meetings of policymakers

A. Lending operations

Between 1998 and 2013 the IDB promoted 11 programs totally or partially allocated to investments in the new educational technologies. The operations approved during the period amounted to US$1202.5 million, and the amount allocated to components devoted exclusively to the introduction of technology in education involved investments for US$187.7 million.

The purpose of these loan operations can be classified into two groups. The first group, which covers most projects, attempts to equalize access to new technologies and computer material between children from different socioeconomic groups. The technological equipment model adopted in this group of projects covers the three primary types of physical environments described in the conceptual framework: i) technology projects related to computer labs, distance learning, interactive radio, connectivity of schools and libraries and multimedia devices; ii) mobile classrooms; and iii) projects based on a one-to-one computer model. The design of these operations reflects the evolution of the technology during the study period. Operations related to computer labs are concentrated in the late 1990s and early 2000s. As the costs of computers decreased, operations based on one-to-one models and mobile classrooms increased.[20]

What types of activities were financed in this first group of projects? Almost all the programs were focused on expanding access to technological infrastructure and provided little guidance on how and when to incorporate these resources in the learning process. In addition, the projects typically defined as educational goals the improvement of multiple skills, or defined only one general objective without specifying a specific area, such as increasing learning in a subject. One exception is the program implemented in the Bahamas, which proposed, as one of the main objectives, setting and evaluating standards of digital skills in line with the demands of the productive sector for both teachers and students.

The second group of operations aimed at expanding coverage of high quality secondary education in remote areas using technology. The group consists of two projects recently approved for the states of Pará and Amazonas in Brazil. Both states have implemented a face-to-face teaching system mediated by technology, based on the production of educational television programs which transmit classes through a satellite communications network, connecting communities whose size does not justify opening a school and which would otherwise have no educational services. These operations finance the equipping of centers with connectivity and communication services, while developing the supply of digital educational content. In the case of ICT use for educational access in low density areas, the objective is similar to that of the many education programs assisted by radio or television implemented in the region in the last 20 years. However, the new programs use technology not only to transmit information to certain target groups, but, above all, to allow interaction between students and teachers through tele- or videoconferencing. Both operations include rigorous evaluations to measure their effect on coverage and student performance.

B. Knowledge products

In addition to lending operations, the Bank invests non-reimbursable resources to promote knowledge generation on relevant issues for the region, channeled through two types of instruments: Technical Cooperation operations, which primarily provide technical support for implementation of operations or projects, and Economic Sectoral Work studies which fund research projects. Since 2001, 27 projects have been approved to produce knowledge products (Table 7). Of the 23 Technical Cooperation operations approved, 12 have been completed, and 3 of the 4 Economic Sectoral Work studies have been completed. The approved amounts per project range from US$40,000 to US$2.5 million with a total investment of US$15.7 million.

In terms of content, the main activities financed fall into four main groups: i) implementation of pilot programs and operations support; ii) content development; iii) impact and process assessments and evaluation methodology; and iv) knowledge dissemination and exchange. A

[20] Annex IV contains a brief analysis of the content of these types of projects and their lessons learned (when the implementation period allows).

brief description of the beneficiary countries, the activities financed and the main results of each of the four groups follows.

i) Implementation of pilot programs and operational support

The demand from countries for knowledge, resources and technical support to implement one-to-one programs led the Bank to carry out intensive work in this area. Ten Technical Cooperations were approved that funded pilot programs or gave technical support to loans in six countries of the region (Colombia, Costa Rica, Haiti, Honduras, Paraguay and Uruguay).[21] One achievement of these TCs was to propose a model for implementation of one-to-one initiatives, based on a review of experiences, which has been assessed by the countries and used for decision-making and program design. This model proposes to coordinate initiatives around the learning needs of students, organizing digital educational resources, connectivity, access to equipment, teacher training, technical and educational support and management strategy and monitoring of learning objectives. In addition, a matrix of costs associated with this type of initiative was developed to draw the attention of the countries to the "total cost of ownership" associated with these programs, which is more comprehensive than the cost of the equipment.

ii) Content development

Four Technical Cooperation operations were approved in this area.[22] The most relevant project was the Technical Cooperation which financed the creation of the RELPE. Its implementation contributed to creating educational portals in member countries of the network. At the start of this project only six of the participating countries had an educational portal. With the resources from this Technical Cooperation and from the countries themselves, the number of countries with an educational portal grew to 18. RELPE is now a recognized and active organization whose goal is to become a community for exchange and collaboration of high-quality educational content to improve the quality of education in Latin America.

In 2008, a regional Technical Cooperation examined how to develop content and technology to enhance student learning in higher secondary schools, compared with technologies that provide basic knowledge for the use of computers or Internet access in 5 countries (Chile, Colombia, Ecuador, El Salvador and Mexico). The activity included review of study plans, evaluation of each country's math teaching strategies, and development of cognitive tutoring modules and

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[21] Pilot project for the educational connectivity program and preparation of an expansion strategy (UR-TC-0104012, 2001); Support for educational innovation with one-to-one models (CO-T1127, 2008); One computer per student in Haiti (HA-T1093, 2008); Support for teachers of XO-OLPC Project (HA-1102, 2009); Incorporation of ICT in the Paraguayan education system (PR-T1064, 2007); Strengthening of incorporation of ICT in the Paraguayan educational system (PR-T1081, 2009); Support for development of an integrated technology in education program (HO-T1149, 2011); Improving the quality of teaching English as a foreign language (CR-T1055, 2009); Pilot instruments to measure 21st century skills in Costa Rica (CR-T1072, 2008); and Incorporation of ICT into the Paraguayan education system (PR-T1064, 2008).

[22] Creation and support for the Latin American Network of Education Portals (RELPE) (RG-T1152, 2005); Tutoring systems for secondary education in Latin America (RS-T1359, 2008); Education For All movement: New educational practices and policy agenda (BR-T1246, 2012); E-learning in LAC 3 personalized learning environments (PLE) (CH-T1118, 2011).

supporting documentation. Finally, a repository of technology-enhanced math learning materials was created.

In addition, two recently approved Technical Cooperations explore new teaching practices that integrate the use of technology into the classroom. In Brazil, a component of the associated Technical Cooperation will finance the design, testing and evaluation of new methods of instruction by combining learning and educational technology. For example, video lessons and digital resources in math, science and Portuguese will be developed and offered to students in public schools via the Internet or locally, and teaching staff will receive training including interactive activities in the classroom. The Technical Cooperation implemented in Chile aims to improve the design of education policies through the development, innovation and identification of new priorities in personalized learning environments (PLE).

iii) Impact and process assessments and evaluation methodology

Technical Cooperations were approved to evaluate the impact of certain technology programs on educational results, and the conditions of implementation necessary to maximize this impact.[23] Most technical support was related one-to-one programs. Seven projects were devoted exclusively to monitoring and evaluating programs underway or to design guidelines for evaluating this type of intervention. The products generated include an evaluation guide to help countries anticipate, measure and determine the impact of this type of intervention. Financing was also granted to the experimental evaluation of the Peruvian government's One Laptop per Child program. This study constitutes the first large-scale experimental evaluation of one-to-one programs in the world, and has revealed a strong demand from governments and other stakeholders for quality evidence on the impact of these programs and how to improve the benefits that they generate.

A Technical Cooperation in Costa Rica evaluated the cost-effectiveness of implementing standardized lessons taught through smart board technology, personal laptops in a computer lab or laptops shared by two students in a computer lab. The methodology proposed includes the design of comparable instruments for delivery of common curricular material (geometry) in the three uses, accompanied by adequate teacher training and the design of the evaluation instruments.

iv) Dissemination and knowledge sharing

The main objective of this area of work was to propose a coherent and systematic view of the use of technology in education. The area was supported with 4 Technical Cooperations.[24] The work

[23] Evaluating one-to-one computing in education (RS-T1334, 2007); Experimental evaluation One Laptop per Child (PE-T1155, 2009); Portable Technology in the classroom, Peru and Honduras (RG-T1968, 2010); One computer per student (BR-T1092, 2008); Experimental evaluation of the One Laptop per Child in Peru (PE-K1003, 2010); Beyond access: ICT use for human development and productivity (RG-K1217, 2010); and Evaluating the benefits and costs of alternative ICT use in education (RG-T1946, 2010).

[24] ICT and regional education seminar sponsorship (RG-X1096, 2010); ICT Impact on education, knowledge network in Latin America (RG-T1709, 2009); Development in the Americas 2011 flagship report: Information and

was coordinated with other international organizations (World Bank, OECD, United Nations Educational, Scientific and Cultural Organization [UNESCO], Economic Commission for Latin America and the Caribbean, Organization of American States, United States Agency for International Development [USAID], and the Korean Information Service for Education and Research [KERIS]) in the belief that a shared vision would benefit the dialogue among the countries. One of the main products was the creation of a framework for action which organizes the variables and components associated with this type of project (Severín, 2011). Dissemination activities were also funded, including the seminar "From chalk to click: Education, technology and learning" organized by the IDB, OECD and KERIS, along with review of experiences through seminars in the countries of the region, and participation in international seminars sponsored by the OECD, KERIS, and the World Bank.

The knowledge dissemination activities financed included the Bank's flagship publication in 2011 (Chong, 2011) devoted to the use of ICT to stimulate development of the countries of the region. One of the chapters of this publication focuses on technology in education and suggests that greater access to computers in schools produces few results. Complementary inputs, such as software, training and teaching support are essential. The chapter also highlights some ICT applications that seem to give promising results, such as spending one or two hours per week to train students in ICT or computer-assisted instruction to speed up math learning. Consequently, the authors recommend giving priority to the careful planning of components and having sufficient budget to finance essential complementary inputs including teacher training.

Lastly, in 2013 the Bank approved a Technical Cooperation that aims to identify and disseminate best practices on the use of broadband for educational purposes. This Technical Cooperation is intended to become a guide for policymakers facing the main development challenges when implementing a broadband technology in education program. The study is directly aligned with the Broadband Initiative, launched by the Bank in March 2013. This initiative allocates significant resources from the Ordinary Capital to support the creation of an institutional and regulatory environment conducive to competition, investment and public policies to speed up access, adoption and use of broadband.

Communication Technologies (RG K1088-2009); Information and Communication Technologies for education (RG-K1069, 2009); Incorporation of technologies in education: Learning from the Korean case (CH-T1077, 2008).

VI. Principles that will guide the Bank’s operational and analytical work

The principles that will guide the Bank's work in technology in education are grouped into three areas: project support, knowledge agenda and collaboration with industry.

A. Support for new technology projects in LAC countries

1. Focus on specific learning objectives

The main objective of any program in technology in education should be to improve student learning, broadly defined to include academic areas (language, math and science), digital and general skills, such as the so-called 21st century skills (creativity, critical thinking, communication and collaboration). However, effective technology in education programs usually focus on specifically defined learning objectives (for example, early reading, and third grade math). This does not mean that other educational objectives are not valued, but focusing on a specific objective tends to increase the chances of success. Focusing on specific objectives could also be the first stage in a long-term plan with broader objectives. In a second stage, the program could focus on other objectives and gradually improve learning in a range of areas.

2. Coordinate three key components

Although the design may vary depending on the challenges present in each education system, the programs financed by the IDB have to guarantee coordination of three basic components:

- *Infrastructure:* ensure that schools have adequate physical and service infrastructure, and that their use is aimed at improving learning (appropriate spaces in schools, electricity, Internet connection and security of equipment).
- *Content*: consistently coordinate distribution of hardware with the software adapted to academic goals and ensure consistency between software and the curriculum. The IDB can play an important role in financing provision of regional public goods in terms of software and translation of technological material which may be useful for all countries in the region (for example, translation of Kahn Academy to Spanish and Portuguese).
- *Human resources*: incorporate intense training activities and support teachers to promote good practices in the use of new technologies in the classroom. Incorporate training of parents and the community in appropriate use of computers outside the school. The IDB recognizes teachers as the most important factor in improving student learning; consequently, it will stimulate initiatives to invest and encourage the training of teachers to teach in the new technological environment.

An effective strategy for implementing these components must include mechanisms for adequate and timely maintenance.

3. Establish a sound monitoring and evaluation strategy

In the design of an intervention it is essential to follow up the intermediate results that should be observed (for example, change in educational practices) and assess the impacts. Monitoring and evaluation provide an opportunity to implement corrective measures and verify that the activities and resources meet the objectives of the initiative before gaining scale.

At the system level, public policies in the area should be based on a diagnosis of key indicators which are now available in a few countries in the region and which are essential for making informed decisions. It is expected that the IDB will help countries generate data and collect more information on the effective use of ICT by students, teachers and school principals, and at the level of public and private investment in technology for learning programs.

4. Ensure gradual expansion and sustained efforts

During implementation of the program, more accurate information is obtained on the effect of each component or the program as a whole on the general objective pursued, on strengthening the educational actors and on building local capacities. To take advantage of this, the Bank recommends designing the implementation of the program in such a way that the expansion takes place gradually. To realize the transformative potential of technology, and for the experience to be successful, significant changes in organization and teaching practices are required. Accordingly, the Bank recommends adopting a perspective of change over the mid-to-long term and a sustained effort over several years. Technology in education should not be considered as an end in itself but as a means for making profound changes in curriculum, teaching and, as a final goal, in student learning.

General recommendation: The IDB will only provide financial support for interventions that have shown positive impact assessments whose costs are consistent with the expected benefits. For interventions that have not been evaluated, the Bank will support and finance pilot or demonstration experiences, with impact assessment strategies clearly defined from the design stage.

The IDB will be expected to encourage the design of program that improve teaching practices and enhance support systems and school management. In the case of programs focused on the learning process, the Bank needs to promote experimentation with different models of guided-use programs to identify the most effective. A feasible policy sequence could include first implementation of a program focused on providing technological resources, followed by a series of guided-use programs focused on specific learning objectives.

B. The Bank's knowledge agenda

The Bank will support knowledge generation through Technical Cooperations and Economic and Sectoral Work studies to support decisions by policy-makers. The Bank may act as a catalyst to overcome market failures and failures of coordination which generate underinvestment in the research sector. The aim is to leverage these resources with contributions from governments and the private sector, exploiting common objectives and economies of scale. The following principles will continue to guide the Bank's analytical work.

1. Support for evaluations of promising programs

The IDB will invest resources and provide technical support to assist countries in developing pilots and evaluations of promising programs that help identify the impact of the interventions, as well as the conditions of implementation that could increase their impact. To improve the chances of identifying successful programs that could be scaled-up in the region, the Bank will have as one of its lines of work the evaluation of promising programs. A lesson learned from the Bank's experience in the region is that programs must be scaled up gradually to identify areas for improvement during implementation of the pilot or the early stages of the project. The strong demand from countries of the region for knowledge, resources and technical support for technology programs (especially one-to-one models) has given the Bank an important comparative advantage in the field of evaluation, which could prove beneficial to identify effective programs.

2. Develop knowledge in prioritized areas

As financial and human resources are limited, the Bank's analytical work should focus on identifying effective learning models in a specific area. The Bank will prioritize development of knowledge in areas where: i) the technology could have most impact on education; ii) the technological solutions identified can be relatively easy to adapt to different countries in the region; and iii) the interventions result in improvements in average learning but also narrow the existing gaps between students from different socioeconomic groups.

It is expected that this strategy to focus on a learning area will maximize the chance of generating strong evidence on a key issue for the region. The problem to be solved will be diagnosed, relevant experiences and pilots identified, and promising solutions developed and rigorously evaluated. A variety of interventions with the same metrics of success and under the same conditions of context will be analyzed. The resulting evidence, together with the capacity created for research and development, will be used to create applications for additional learning areas, in the following stages.

3. Establish long-term projects

The experience of the IDB and other actors in the area of knowledge production for policymaking suggests establishing long-term projects. The Bank will implement projects in selected contexts to increase efficiency in project design and implementation by exploiting synergies and economies of scale. This strategy takes advantage of the capacity for developing a project which includes effective collaboration with government, researchers and local implementers, knowledge of context, administrative data, measurement instruments, and the team accumulated knowledge. Moreover this work strategy creates synergy through the implementation of simultaneous or sequential data collections.

4. Promote knowledge sharing and dissemination

The IDB will seek to identify successful uses of technology in education to improve learning. The countries of the region are investing in technology in education, and expanding resources for incorporating technology in schools, but there are still important gaps in knowledge about what models improve student learning. The IDB can play a key role in ensuring a high return on investments by governments through knowledge creation and identification of promising uses and best practices in the area, along with their dissemination in the region. In fact, the Technical Cooperation RG-T2337, recently approved, will identify best practices in the use of Internet for educational purposes and summarize them in an electronic book, which could be an important input for countries seeking to advance this line of work. The Bank will promote dissemination and knowledge sharing of evidence and lessons learned in the region.

C. Collaboration with industry

The Bank recognizes the importance of cooperating with the private sector and civil society in the search for innovative and successful technological learning solutions that improve the quality of education in the region. Several factors explain the private sector's interest in establishing a close dialogue with the Bank. First, better quality education increases the productivity of the workforce, a key input for the competitiveness of enterprises. Second, technology in education represents a huge market opportunity: the global education market is estimated at US$7.8 billion, and is growing annually at about 18%. Third, broadband penetration is 36% and growing rapidly while demand for technology products and services is likely to continue growing in the next few years.

Several major actors are operating in crucial areas for implementing technology in education programs: infrastructure, content and professional development. According to the needs of LAC countries, the private sector will operate with the IDB as:

1. Supplier of goods and services. The private sector can participate in the contracting and procurement processes of lending operations or TCs.
2. Financial resources client. The Bank can provide financing for private organizations that are expanding educational services and products by means of loans or guarantees through its windows for operating with the private sector.
3. Partner in social responsibility areas. The private sector and the IDB can develop strategic alliances or specific partnerships, providing financial or in kind resources to support policy dialogue and knowledge generation.

Cooperation between the private sector and the IDB in areas of social responsibility could materialize in activities such as:

1. Producing a publication that presents the view of the industry in this sector, backed by the main actors in the interests of promoting public policy dialogue and cooperation in the sector.

2. Cofinance events to disseminate and share knowledge and lessons learned among countries and inside countries, the private sector and representatives of the education sector.
3. Cofinance pilots to generate new evidence as input for policy recommendations and project design.

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Annex

Annex I: Explaining program impacts on academic achievement using selected variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Guided use	0.11**									
	(0.03)									
Use in school		0.01								
		(0.04)								
Duration (months)			0.00							
			(0.01)							
Duration > 8 months				0.06						
				(0.07)						
Training > 2 days					0.05					
					(0.08)					
India						0.09				
						(0.06)				
China						0.05				
						(0.04)				
Implementation by government							0.04			
							(0.08)			
Lower primary grades								0.05		
								(0.04)		
Number schools									-0.00008	
									(0.00032)	
Number students										0.00001
										(0.00001)
R-squared	0.15	0.00	0.00	0.04	0.02	0.08	0.01	0.04	0.00	0.03

Note: * and ** indicates statistically significant impacts at 10% and 5%, respectively

Annex II: Impact of guided programs on academic achievement: Robustness analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Guided use	0.11**	0.11**	0.13**	0.11**	0.11**	0.13*	0.16**	0.11**	0.11**	0.10**
	(0.03)	(0.03)	(0.05)	(0.04)	(0.04)	(0.06)	(0.07)	(0.03)	(0.04)	(0.03)
Use in school		0.01								
		(0.03)								
Duration (months)			0.01							
			(0.01)							
Duration > 8 months				0.06						
				(0.06)						
Training > 2 days					0.05					
					(0.06)					
India						0.00				
						(0.08)				
China						-0.04				
						(0.05)				
Implementation by government							0.12			
							(0.08)			
Lower primary grades								0.01		
								(0.04)		
Number schools									0.00001	
									(0.00024)	
Number students										0.00001
										(0.00001)
R-squared	0.15	0.15	0.19	0.19	0.18	0.16	0.25	0.15	0.15	0.15

Note: * y ** indicates statistically significant impacts at 10% and 5%, respectively

Annex III: One-to-one programs in Latin America and the Caribbean

	One-to-one program	Number of devices	Equipment	Beneficiaries	Scope	Education level	Institution	Bank support for program	Bank support for other programs
Argentina	Conectar Igualdad, 2010	4,000,000	Intel Classmate PC, with Windows operating system	Students	National	Secondary	Ministry of Education	No	Loan (AR-L1108, 2010): PROMEDU III, mobile digital classrooms in primary (equipment, training and content, process evaluation)
Bahamas	No								Loan (BH-L1003, 2005): technology integration to the curriculum and teacher training in ICT (secondary)
Barbados	No								Loan (BA-009, 1998): integral program base on multimedia (all levels)
Belize									No
Bolivia	Una Computadora por Docente, 2006	110,000	Laptop Lenovo model E47G	Teachers	National	Initial, primary and secondary	Ministry of Education	No	No
Brazil	Um Computador por Aluno (PROUCA), 2009	150,000	XO, Classmate PC	Students and teachers	National	Primary and secondary	Presidency of the Republic, Ministry of Education	CT (BR-T1092) 2008: documentation and evaluation of pilot experiences in five Brazilian schools	Two loans: (BR-L1328, 2013A) and (BR-L1327, 2013A) coverage expansion through a distant learning technology-based model. One TC (BR-T1246, 2012): new instruction methods using technology
Chile	Laboratorio Móvil Computacional (LMC), 2009	250,000	Netbooks	Students	National	Primary (3 and 4)	Ministry of Education	No	TC (CH-T1118, 2011): evaluation of personalized learning environments
Colombia	Un Computador por Niño, 2008	22,000	XO	Students	Pilot	Primary	Foundation Pies Descalzos (FPD)	CT (CO-T1127) 2008: supports the FPD in OLPC execution in Quibdó, Barranquilla and Bogotá (evaluation, teaching development)	

Costa Rica	Conectándonos, 2007	1,500	XO	Teachers and students	Pilot	Primary	Ministry of Public Education, Foundation Quirós Tanzi	No	Three TC: (CR-T1055, 2009): evaluation of technology use for learning English; (CR-T1072, 2011): measurement of 21st century skills and (RG-T1946, 2010): evaluation of alternative models for Math learning
Ecuador	Mi Compu, 2010	4,000		Teachers and students	Pilot, Cuenca and La Libertad	Primary	Ministry of Education		No
El Salvador	Cerrando la brecha del conocimiento (CBC), 2009		XO with GNU/Linux operating system	Teachers and students	National, schools with low resources	Basic (grades 1 to 9)	Ministry of Education	No	Loan (ES-0108, 1998): component on technology introduction for learning using multimedia (primary)
Guyana	One Laptop per Family Guyana (OLPFG), 2010	31,000	Notebooks Chinese manufacturer, Haier	Teen and Community Development Groups	National	Primary and secondary	Office of the President	No	Loan (GY-0063, 2002): interactive radio and computers for 20 schools (primary)
Guatemala								No	No
Haiti	OLPC Haiti, 2008	14,000	XO	Students	Pilot	Primary	Ministry of Education	CT (HA-T1093) 2008: one-to-one computer trial in context of extreme poverty	No
Honduras	Una computadora por niño, 2012	41,000	XO students and teacher notebooks	Students and teachers	National	Primary (3rd and 6th grades)	Ministry of Education	Loan (HO-L1062) 2011: purchase of equipment, content, impact evaluation, teacher training + two CT (RG-T1968) 2010: collection of preliminary data, and HO-T1149 2011: development of manuals and coordination	No
Jamaica	OLPC Jamaica, 2008	115	XO	Students	Pilot (The August Town Primary School and Providence Methodist Basic School)	Primary	OLPC Jamaica	No	Loan (JA-0059, 2000): distant education and innovative pedagogical practices using multimedia (primary)
Mexico	OLPC Mexico, 2008	240,000	XO	Students	Pilot (Sonora, Nayarit, San Luis Potosi,	Primary	Telmex	No	No

					Mazahuas)				
Nicaragua	OLPC Nicaragua, 2008	30,000	XO	Students	Pilot	Primary	Foundation Zamora Terán, support from Ministry of Education	No	No
Panama	Tecnología para todos, 2012	93,000	Classmate	Students	National	Secondary	Ministry of Education and AIG	No	No
Paraguay	Paraguay Educa, 2008	4,000	XO	Students and teachers	Regional (Caacupé)	Primary	Paraguay Educa	CT (PR-T1081) 2009: one computer per child in Caacupé (equipment, content and evaluation)	No
Peru	Una laptop por niño, 2008	797,000	XO	Students and teachers	National	Primary	Ministry of Education	Two CT: PE-T1155, 2009: design, development and publication of results of the experimental evaluation, and RG-T1968, 2010: second collection of data	No
Dominican Republic								No	No
Suriname									
Trinidad and Tobago	eConnect and Learn Programme (eCAL), 2010	69,000	HP 425 notebook PC	Students (+3,000 teachers)	National	Secondary	Ministry of Education	No	Loan (TT-0023, 1999): sub-component to improve ICT competences using multimedia (secondary)
Uruguay	Plan Ceibal, 2007	1,000,000	XO laptops and Intel Classmate	Students	National	Primary and secondary	LATU and CITS	Loan (UR-L1058) 2009: not to purchase equipment, but content, evaluation and continuous training	TC (UR-TC-0104012, 2001): pilot experiences and proposal for expanding the use of technology in the education system
Venezuela	Proyecto Canaima, 2008	3,300,000	Classmate	Students and teachers	National	Primary	Ministries of Education and Science and Technology	No	No

Source: Severin and Capota (2011) with updates using online sources. Note that the number of devices distributed is updated to different years for the different programs based on the available sources for each of them. AIG: National Authority for Government Innovation; CITS: Center for Technological and Social Inclusion; CT: Technical Cooperation; LATU: Technological Laboratory of Uruguay.

Annex IV: Description of the Bank's lending operations

a. Technology labs, computer rooms and multimedia

These projects had a dual purpose: equipping schools with computer and multimedia facilities to equalize access to this type material for children from different socioeconomic backgrounds, and increase digital and/or academic skills.[25] They were targeted at both primary school (El Salvador, Guyana and Jamaica) and secondary (Bahamas, Trinidad and Tobago). In the case of Barbados, the aim was to cover all public institutions in the compulsory education system although due to a series of delays it was not able to reach the level of coverage originally proposed.

With respect to the type of technological infrastructure, almost all projects in this group (4 out of 6) were based on purchase of computers, printers and servers to create computer, science and technology labs and equip the libraries. Some also funded purchase of devices in line with the technology available at that time (CD-ROMs and videos, slide projectors and screens, radios and cassette players) or distance education programs.

One aspect to note is that these programs were designed as integrated technology projects, whose implementation incorporated teacher training and curriculum development components in an effort to successfully improve learning through technology. In Barbados and El Salvador, the programs incorporated important components that framed the investment in the financed technology: teacher training for technology use and equipment maintenance, training of professionals in the education sector for development of multiple support systems for the program, development of teaching guides, reforms of the study plan to promote new teaching strategies and systematic integration of software in the classroom. The Barbados operation also included the creation of the Center for Software Review and an education evaluation center at the University of the West Indies to ensure systematic support for the reform. Although less ambitious in their duration, the Guyana and Jamaica programs also have some type of teacher training to effectively integrate technology into their instruction.

Although none of these projects had rigorous impact assessments which might have been able to attribute improvement of student performance indicators to the incorporation of technology into the curriculum, certain lessons can be extracted from the closure reports of these operations.[26] For example, in Barbados technology training for teachers was provided for a year and a half before the technology reached the schools. This delay discouraged many teachers who were initially enthusiastic and increased the resistance of teachers reluctant to implement new teaching strategies in the classroom. Moreover, the final evaluation of this project emphasized the importance of acquiring the latest quality technology accompanied by a robust maintenance strategy. In an IDB study, many teachers also cited the unreliability of the technology as one of the main reasons for not using it more in their classrooms. The independent evaluation of the operation underscored the importance of guaranteeing Internet connectivity to access

[25] The six loan operations in this category are: El Salvador, 1998: "Support Program for Educational Technologies" (ES0108); Barbados, 1998: "Program for Improvement of the Education Sector" (BA0009); Trinidad and Tobago, 1999: "Secondary Education Modernization Program" (TT0023); Jamaica, 2000: "Project to Support Primary Education" (JA0059); Guyana, 2002: "Basic Education Access and Management Support" (GY0063); Bahamas, 2005, "Investing in Students and Innovative Programmes for the Reform of Education" (BH-L1003).

[26] In general project evaluation strategies were either not implemented or partially implemented, limiting the information we can recover on the quantitative impact of the use of technology on digital or academic skills.

online resources, in particular a portal with technological content developed by the ministry, related to the curriculum.

b. Digital Classrooms

The only IDB operation that supported technology projects based on digital classrooms is Argentina's Program to Support the Policy on Improving Equity in Education (PROMEDU II).[27] In this project, a subcomponent of new ICT in education (US$23.8 million) was financed to improve learning at primary level through 1,516 mobile digital classrooms. This is an intermediate model between the computer room and the one-to-one scheme. The digital classroom has 32 laptops and a projector that moves from room to room; the teacher decides when to incorporate them into the lesson. This program was created in line with the national plan for one computer per student (*Connectar Igualdad*), which the Argentine government is implementing at secondary level. The program also envisages training 26,800 teachers through the creation of 240 centers for educational renovation and innovation. The aim is to promote professional development of teachers, create opportunities for exchange of experiences of educational practices and facilitate teachers' access to bibliographic, computer and multimedia resources, which are also being developed under the program. The program also includes a process assessment to determine how teachers use technology in the classroom.

c. One-to- one models

The Bank funded two operations to implement one-to-one models in Uruguay and Honduras.[28] Both programs aim to improve the quality of education by offering the following support for teachers: i) training services in reading, writing and math and use of technology; ii) support and technical assistance in the classrooms to strengthen use of the knowledge acquired in the training; and iii) development of educational content and resources.

However, IDB's role is different in each project. In Uruguay, the government financed with its own funds the investment in infrastructure and technological resources under the Ceibal plan, while the Bank's program offered support for the plan: implementation of teacher training and support, institutional development for program evaluation and creation of initiatives to broaden the social impact. In Honduras, the investment program financed by the IDB will provide technology (hardware and software) in 545 beneficiary schools with a one-to-one model (grades three to six). This includes computers for students and teachers, servers and networks that provide connectivity and access to educational resources and administrative support system.

Regarding the evaluation of these programs, the governments of Uruguay and Honduras requested incorporation of impact and quality assessments and experimental (or quasi- experimental) evaluations to measure the impact of the interventions on student learning and the internal efficiency of the participating schools. However, in the case of Uruguay it was not possible to implement an impact assessment and, hence, a process assessment was designed, which is currently underway.

[27] PROMEDU II (AR-L1108, active).

[28] Uruguay, 1999: Program to Support Expansion and Consolidation of the Ceibal Plan (UR-L1058, active); Honduras: Elementary Education and Technology Integration Program (HO-L1062).