"WHAT IS THIS FOR?"

Scientific inquiry as a key to teaching twenty-first century science, technology, engineering, and mathematics (STEM) skills

Case study done with LAB4U

IDB
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INDEX

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EXECUTIVE SUMMARY

Can Lab4U technology enhance the interest of students and their academic performance in physics?

This document presents the impact assessment process and results of a pilot project on the learning of physics through technology among upper secondary education students in Sinaloa, Mexico. The purpose of the project is to establish a correlation between student motivation and academic performance within a school environment that enables the access to a technology tool within a classroom, such as Lab4Physics, a Lab4U model.

This report comprises an introduction and four sections. The first section describes the current state of education in Latin America, in general, and of Mexico and the state of Sinaloa, in particular. The section points to the low level of interest as a key factor of school dropouts as well as the need to close the digital divide in the region. The second section describes the pilot project´s implementation methodology and the assessment measurements used. The third section describes the findings and conclusions. The fourth and last section records the lessons learned and the report´s recommendations.

The above will provide an understanding of the key components that have led to the success of the project, especially that relating to the ownership of the teachers, students, and education authorities. Furthermore, it is hoped that the results not only will inspire similar initiatives in the future within the region in terms of capturing the interest of students in the realms of science, technology, engineering, and mathematics, but also that they will lead to an improvement in student performance so as to prepare them to be active players in the Fourth Industrial Revolution.

Keywords: education, technology, STEM, motivation, academic performance, Physics, secondary school, Sinaloa, Mexico, pilot project.

INTRODUCTION

How do students in Latin America learn a principle of physics such as that of centripetal force?

One can imagine a traditional classroom of secondary students attentively listening to a professor explain how to calculate the speed and size of an object. The students are quick to copy a scientific formula from a blackboard, one they later will memorize in an attempt to grasp the complexity of the subject. At the end of class, confused, they look at one another and think, "This doesn´t make sense. What is this for? I´ll never apply it to real life!" The lack of scientific inquiry and application, which should guide students from theory to practice, originates from a great void: the lack of infrastructure and collaborative spaces that encourage experimentation.

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This scenario stems from the fact that 88 percent of school science laboratories in Latin America are not adequately equipped (Cabrol and Székely, 2012). It is not surprising, therefore, that students in the region are ranked in the bottom third of the Program for International Student Assessment (PISA) assessment in science (Bos and Elías, 2016). What are the alternatives to solving this anomaly? What would it take to change teaching methods and teacher/student participation?

One can picture a scenario of no laboratories and disinterested students; one where teachers and pupils alike should be able to access innovative technology for scientific inquiry—technology that will guide teachers without the need for a laboratory; technology that

is able to make use of the sensors that are readily available on students' cellular phones. This possibility will require a high level of technology integration to support teachers. By rotating a cellular phone and calculating those velocity and size formulas written on the blackboard by the professor, students would have discovered that they would have been able to experiment with centripetal force on their own.

SINALOA

- **Capital:** Culiacan Rosales
- **Population:** 2.767.761
- **No. Students of the case study:** 10.000

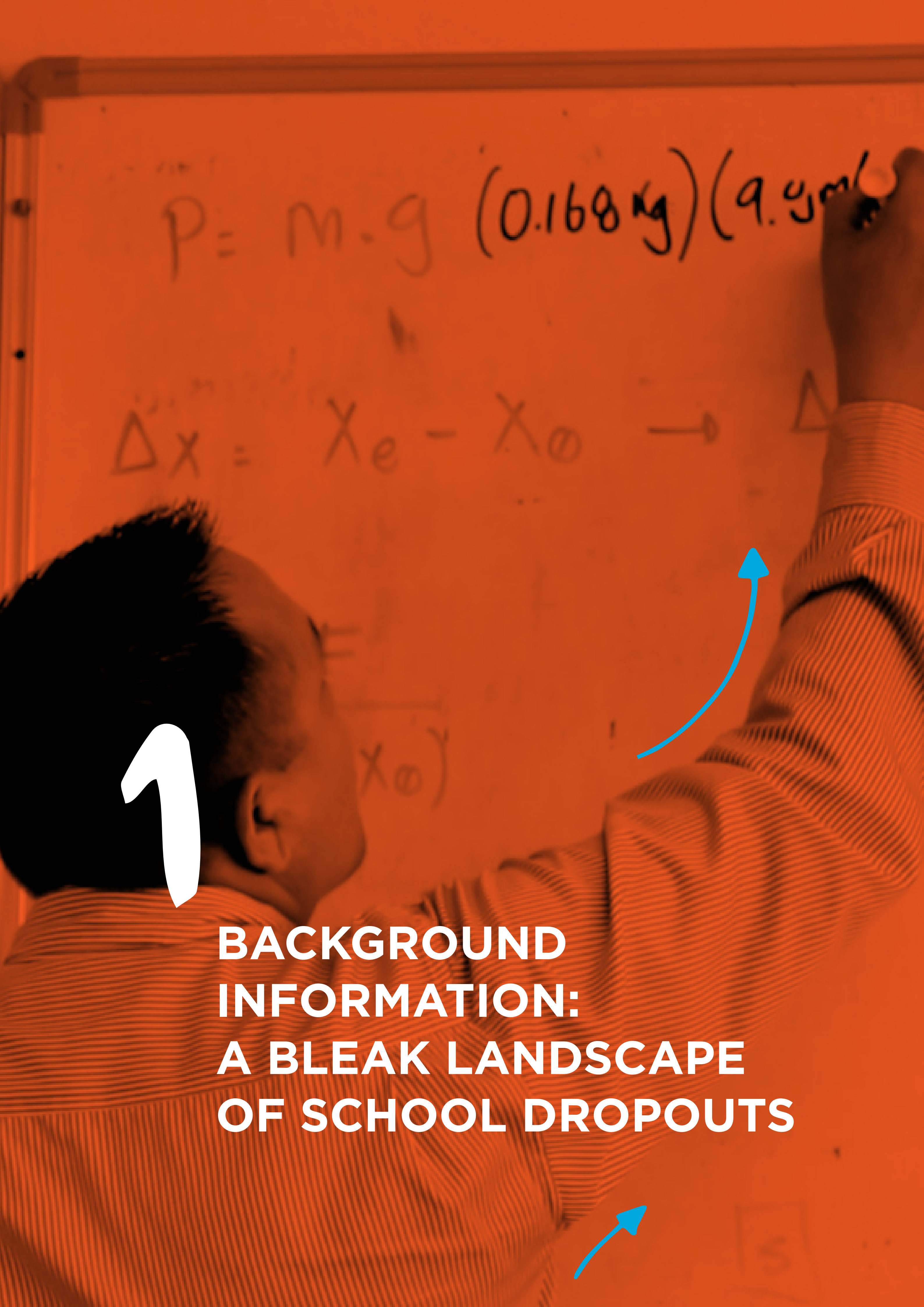
The case study, whose design and technology application are based on the reuse and conversion of built-in cellular sensors in scientific instruments, was carried out in collaboration with Lab4U[1], together with the Regional Government of Sinaloa, Center for Educational and Social Studies of Mexico (Centro de Estudios Educativos y Sociales, or CEES), and Inter-American Development Bank (IDB).

The study evaluates the elements required for the scientific learning of teachers and students. It also describes the impact that was evident following introduction of this technology—as depicted above—in the classrooms of 10,000 secondary school students in Sinaloa, Mexico.

The pilot project's key successes include the training of teachers and their participation as agents of change in incorporating technology into the classroom. This should lead to an increased interest and improvement in the performance of physics students, simultaneously motivating teacher and student alike.

1

Lab4U is a Chilean start-up technology company that uses built-in sensors on smartphones and tablets to transform these devices into small, portable laboratories. Lab4Physics is a Lab4U software application that was specially created for teachers of physics and students alike. The inventor, Komal Dadlani, states that she developed Lab4U "to democratize science and change the way we teach it".



1 BACKGROUND INFORMATION: A BLEAK LANDSCAPE OF SCHOOL DROPOUTS

With the exception of three countries, Latin America's attendance rates have reached 95 percent in primary schools and 85 percent in secondary schools (Duryea and Robles, 2017). Nevertheless, while secondary school attendance has increased by 10 percent in the last 10 years, the school dropout issue remains critical: one out of every two youths does not complete high school. This implies that over 43 million Latin American between the ages of 15 and 29 (31 percent of the region´s young population) have failed to complete secondary school and lack the necessary preparation to enable them to enter today´s competitive job market (Rivas and Delgado, 2017).

A leading reason for school dropouts in Latin America—beyond economic factors that are attributed to 19.3 percent—is the lack of interest, representing 26.3 percent of secondary school students (Graduate XXI, 2017). In the face of this, the Inter-American Development Bank has created the Graduate XXI program, a program that finances this project as part of a broader initiative to advance in-depth research, analyses, and public debate on the underlying causes of high school dropouts in the region and to seek solutions.

SINALOA, MEXICO: AN OPPORTUNITY TO EXAMINE

During the past 25 years, efforts have been made to prevent school dropouts in Mexico's education system. A variety of scholarship programs are on offer as well as compulsory attendance in primary and secondary (ages 12 and 14) schooling as well as in upper secondary education (USE) (i.e., last three years of education).

While the dropout rate in Mexico's primary and secondary schools is 0.5 percent and 2.2 percent, respectively, the rate at the USE level has remained at 13 percent per annum—almost 40 percent during the entire cycle—despite the efforts and resources invested in reverting the situation (GoM, 2016). The reasons are similar for the rest of Latin America. The National School Dropout Survey (Encuesta Nacional de Deserción en la Educación Media Superior), conducted by the Government of Mexico, indicates that in addition to economic reasons, the second cause for school dropouts relates to the lack of interest shown by students in their studies as well as a dislike of school (19.3 percent) (GoM, 2012).

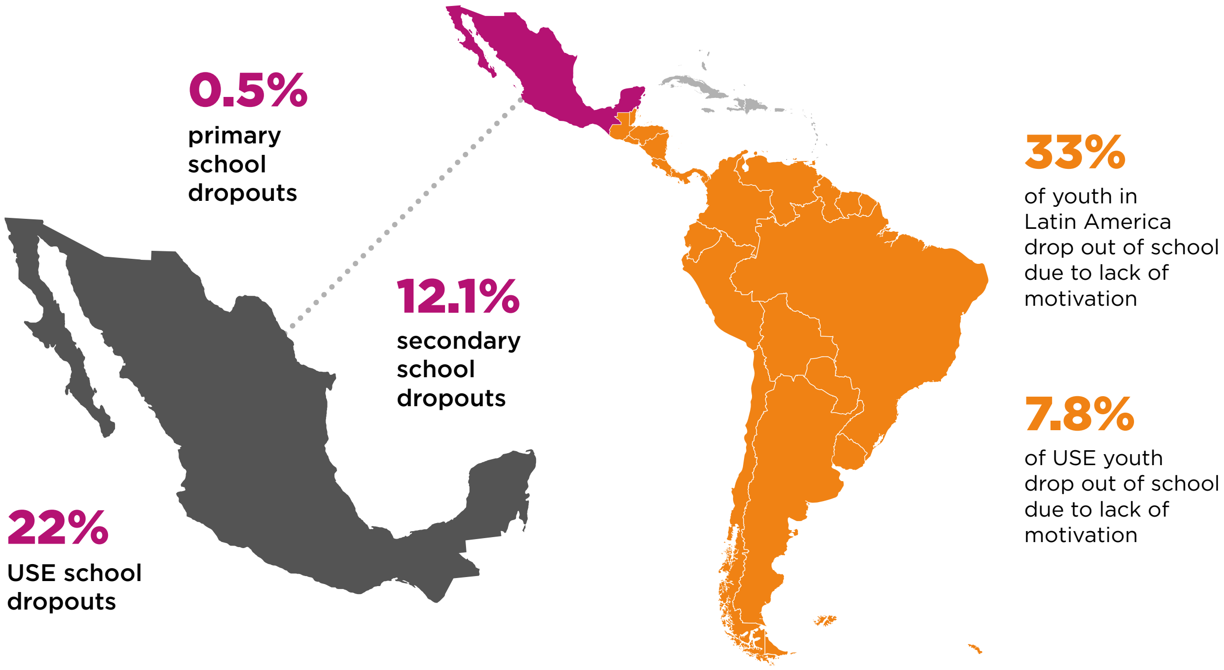
The negative consequences of prematurely abandoning one's studies are serious, the most critical being reduced employment opportunity in the labor market (OECD, 2016). In Mexico, 22 percent of youth are neither in education nor employed, and do not seek to study or work (referred to in Mexico as ninis). The term, ninis, classifies them as inactive during those years they are considered to have high productive value.

The State of Sinaloa, with a population of 2,767,761 million and where the pilot project was carried out, is located in Northwestern Mexico. It ranks 15th among 32 states in the National Science, Technology, and Innovation Ranking (GoM, 2013). According to the Scientific and Technological Consultative Forum (Foro Consultivo Científico y Tecnológico, or FCCyT), Sinaloa also ranks 24th in science, technology, and innovation and 19th in scientific and innovative production.
In Sinaloa, the USE dropout rate is 9.1 percent, while the average school sample dropout is 10.79 percent (Figure 1). For the school year during which the assessment was performed, Sinaloa had a total of 132,680 students enrolled in USE (GoM, 2017).

HOW TO CREATE LEARNING ENVIRONMENTS FOR SCIENTIFIC LEARNING

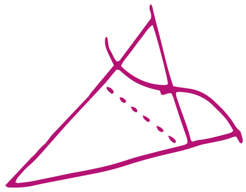
Since only 22 percent of schools in Latin America have the necessary laboratories and instruments to participate in the scientific inquiry and methodology described above, the question is whether this deficiency is a factor in the low performance and scant interest of students. Most students currently tend to take science subjects that focus on theory, without acquiring or applying the necessary skills for scientific methodology, such as critical thinking, creativity, and collaborative work.

Figure 1 / Dropout Rates and Factors in the State of Sinaloa Mexico Compared to Mexico as a Whole and Latin America



Source: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Educational Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

Note: USE = Upper School Education.



A comparison of the skills required in the twentieth century model against that of the twenty-first century shows evidence of a recent shift from that of concept learning and basic processes to that of developing hypotheses and scientific inquiry. This transition offers a plethora of possibilities that go beyond theoretical scientific content, placing the student in a factual life. Figure 2 compares and highlights the relevance of scientific literacy that is required in the twenty-first century education model (Scanlon, 2004).

DIGITAL LITERACY AS A GATEWAY TO THE LABOR MARKET

The change toward a skills-based educational approach will prepare students for a future that is uncertain in terms of employment. It is expected that by 2030, over half of the world´s youth will have reached adulthood without the necessary skills not only to prosper in a career but also for life in general (Pombo, Gupta, and Stankovic, 2018).

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Figure 2 / Twentieth Century and Twenty-First Century Science Education Models

20th Century Model (science skills required)	21th Century Model (science skills required)
Covers basic subjects: physics, chemistry, biology	Seeks to understand how the world works
Covers key definitions, formulas, and concepts	Seeks to develop skills to formulate and text scientific hypotheses
Familiarizes students with basic laboratory procedures	Seeks to develop skills to raise probing questions and design experiments
	Seeks to build things on the basis of scientific principles
	Seeks to apply principles from all disciplines
	Seeks to develop scientific creativity

Source: Author's elaboration based on Scanlon (2004).

In Mexico alone, automation could transform and/or replace 9.8 million jobs. Added to this, 42 percent of companies experience difficulties in hiring personnel, given that much of the knowledge taught in schools does not adequately prepare individuals to enter the labor market (Martinho-Truswell et al., 2018).

Although there are training programs that support the emerging skills of the Fourth Industrial Revolution and the digital inclusion of Mexico´s population (Table 1), these do not directly address the profile of the student population studied in this pilot project, as described in the following section. Therefore, there is a need to create a new space for the investment and exploration of digital inclusion.

Table 1 / Digital Inclusion Programs in Mexico

Program	Purpose	Population
@prende 2.0	Promote the development of digital skills and computational thinking	25 million students enrolled at the basic education level 1.5 million teachers
MéxicoX	Online platform of free courses	Open to the public: 2 million current subscribers
Código X	Promotes the inclusion of girls and women in Information and Communications technology	Mexican girls and women
Mujer Migrante	Web portal that provides information about family members abroad. Includes E-commerce training.	Migrant women currently outside of Mexico
Industrial Innovation Centers	Under the supervision of the Ministry of Economy, seeks to support the adoption and development of new technologies, based on the needs of each industry and the labor market.	17 centers throughout Mexico

Source: Martinho-Truswell et al. (2018).

2 THE PILOT PROJECT

Given this background, the pilot project carried out in Sinaloa focused on two types of USE certification, the general and the technology baccalaureates.[2] The opportunities that an education in the sciences can offer were taken into account as was the potential of this learning toward a smooth transition into the necessary skills of the twenty-first century. In parallel, Lab4U had developed a technology, the Lab4Physics, a mobile application that offered a comprehensive strategy to enable schools to radically reduce not only the cost of a science laboratory, but also the relevant educational content of physics experiments that involve students and teachers alike.

DESIGN AND METHODOLOGY

The change paradigm sought by the intervention suggests that if physics teachers were adequately trained and students were to use the Lab4Physics application, the latter would be able to experiment with scientific content, thereby increasing motivation and improving academic performance. The pilot`s main objectives were to **(i) promote the teaching of physics and foster an interest in educational content by way of innovative Lab4Physics technology; and (ii) provide physics teachers the necessary training in a way that will foster sustainable learning and increase student engagement.**

There are two innovative elements that intersect in Lab4Physics, each of which has the ability to not only modify the level of academic achievement but also to change the perception of students about the applicability and relevance of educational content as well as their attitude toward it. The first element is the approach to learning physics, which is a branch of science, technology, engineering, and mathematics (STEM). The second is the use of information and communication technologies (ICTs) to attract youth and make their learning experience more relevant.

The study consisted of a cluster sampling method, given that the intervention was carried out in the school environment, and the impact was measured at the level of the individual—the student in this case (EASE, 2018). The intervention consisted of providing a group of USE third semester students from the State of Sinaloa the opportunity to carry out 10 physics experiments with the Lab4Physics application.

PRODUCT ADAPTATION

The mobile software designed by Lab4Physics requires teachers to use smartphones and/or tablets as lab instruments, at the same time enabling students to experiment and develop new skills. The experiment in Sinaloa, however, required some adaptations in terms of the local curriculum and context.

2

While technology baccalaureates were originally designed as a path to a working life, the main difference today between both subsystems is that the former is directly ascribed to the educational authorities of the State of Sinaloa, while the latter depends on federal authorities headquartered in Mexico City.

Curricular Alignment

Mexico's Physics 1 is a special module with 10 experiments relating to the basic learning of movement and force. The experiments are aligned with Physics 1 within the general baccalaureate curriculum and that of the technology baccalaureate, the latter taught in the second year of USE. They align with the curriculum of the Ministry of Public Education (Secretaría de Educación Pública, or SEP) (CEES, 2018).

Adaptation to the Local Context

In order to carry out this adaptation, a group of physics teachers was selected by the State of Sinaloa's Ministry of Public Education to participate in the project. The teachers were to ensure that the content, approach, language, and pedagogical method were within the educational framework for the student population.

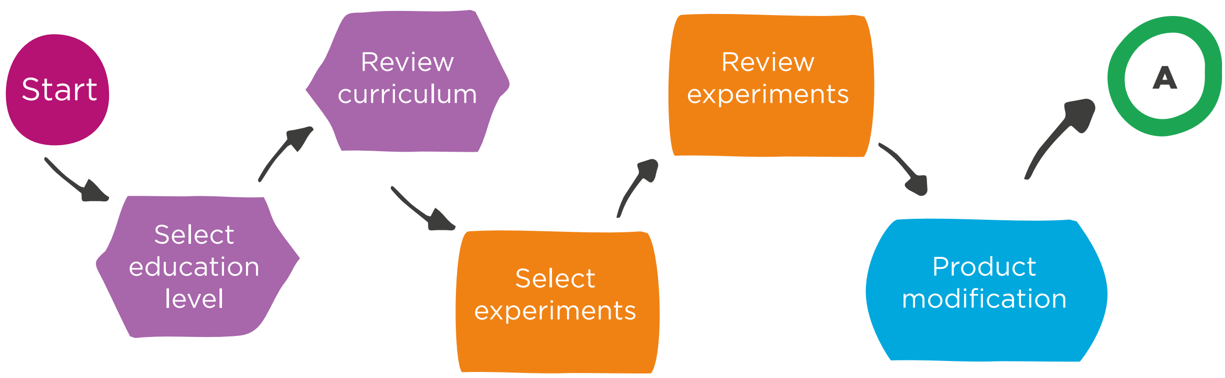
Based on the information [from teachers], the Lab4U team developed a model, tailored to the Mexican context, with 10 pre-selected experiments. Lab4Physics thus included a presentation, as well as instructions relating to each experiment in four main segments: **(i)** description of the experimental arrangement; **(ii)** definition of the roles required for each experiment; **(iii)** instructions on how to take measurements; and **(iv)** a final analysis.

Each step was clearly explained by Lab4Physics, with teachers providing additional instructions including guidance on how to raise questions and discuss uncertainties during the experiments, debate among peers, and the expected experiment outcomes. It is essential to highlight that the contents and language of the tools were adapted only for those involved in the project (EASE, 2018).

UNIT OF ANALYSIS

The project sample was configured on the basis of students from two educational subsystems in the State of Sinaloa. The first constituted those from the baccalaureate schools (Colegios de Bachilleres del Estado de Sinaloa, or COBAES) during the August–December semester of 2017, while the second included those students from the technology baccalaureate schools during the January–May semester of 2018.

Figure 3 / Lab4Physics Adaptation and Modification Process for Sinaloa



Source: Evaluation of processes prepared by the Center for Educational and Social Studies (Centro de Estudios Educativos y Sociales, or CEES), Mexico.

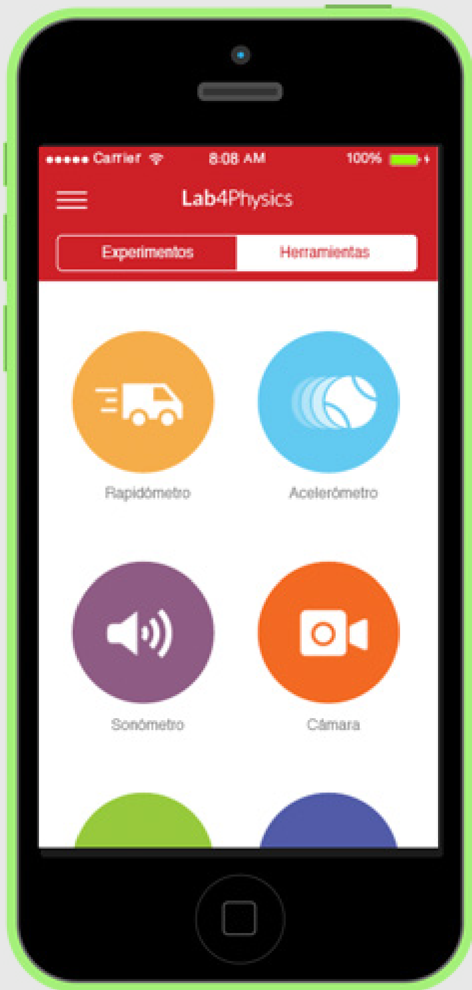
The municipal schools selected were in Los Mochis, Mazatlán, and Culiacán. The selection of COBAES schools was conducted by CEES, based on towns with a minimum of five thousand inhabitants.

Once the schools were identified, they were randomly assigned a treatment and control status. This was followed by balance testing at schools by the CEES team in order to verify that control and treatment groups were statistically equivalent.

Table 2 / Distribution of Schools by Mexico's Center for Educational and Social Studies, by Municipality and Sample Group

Municipality	Number of schools	Control	Treatment
Los Mochis	17	7	10
Mazaltan	9	2	7
Culiacan	20	10	10

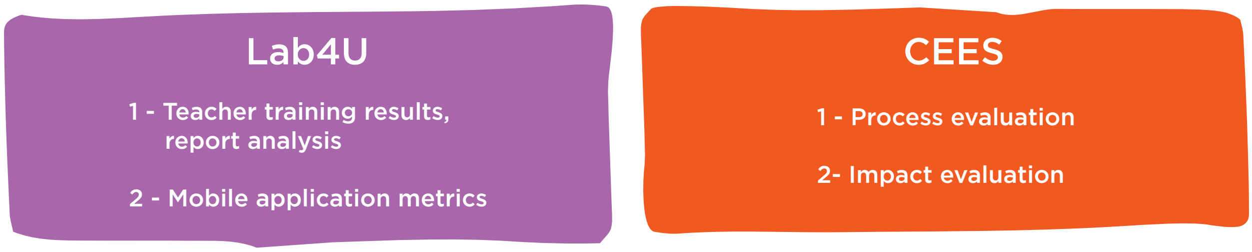
Source: Evaluation of processes prepared by the Center for Educational and Social Studies (Centro de Estudios Educativos y Sociales, or CEES) of Mexico.



Lab4Physics is a mobile application that uses built-in mobile sensors to improve physics class through experimentation and the use of the accelerometer, the camera and the microphone to easily measure, graph and analyze the changes in physical properties.

Scan the QR code to download the app.

Infograph / Summarizing and comparing the measurement instruments



Source: Author's elaboration on the basis of results obtained from the evaluation of processes prepared by the Center for Educational and Social Studies (Centro de Estudios Educativos y Sociales, or CEES) of Mexico

MEASUREMENT INSTRUMENTS

The Lab4U operational and CEES evaluation teams focused on the qualitative and quantitative analyses of the pilot project. Measurement instruments for each are described below.

LAB4U: TEACHER TRAINING AND APPLICATION METRICS

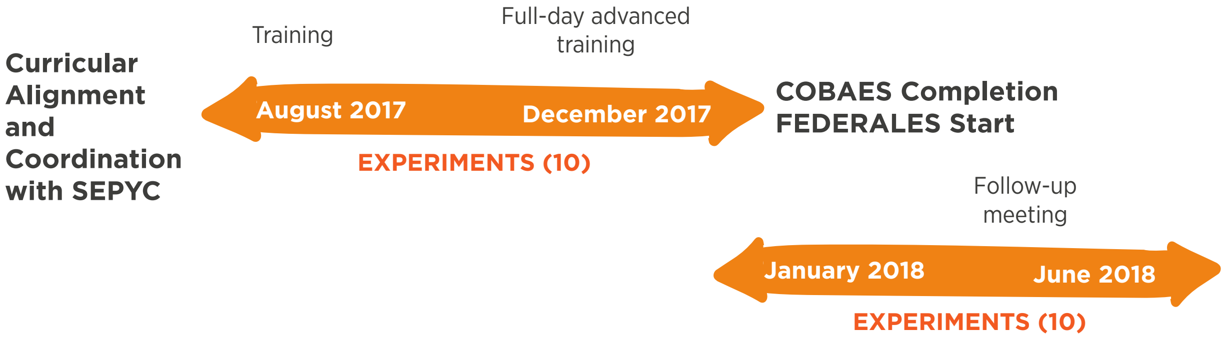
The first operational activity performed by the Lab4U team centered on teacher training. Two full-day face-to-face meetings were held with 80 physics professors and their assistants. Teachers from the treatment group were invited to participate in a process relating to the use of the tool. They were provided with the details of each experiment, information on the materials to be used, instrumentation conditions and periods, and expected classroom results.

Teacher training sessions lasted approximately six hours and included the details of the tool; a description of the 10 experiments to be performed (of which at least four were fully adopted at the time of the teacher training); provision of a Lab4U manual; the important points of each experiment; and a time to reflect on possible additional experiments to boost their innovative spirit. Figure 5 illustrates the timeline of the project and the Lab4U teacher training.

En cuanto a las métricas utilizadas para la aplicación Lab4U, estas incluyen la frecuencia y duración de cada experimento, así como el análisis de la interacción de cada usuario (docente o estudiante). Estas métricas, representadas en un tablero de control, sirven como estudio independiente de evaluación y también como corroboración de los resultados obtenidos por el grupo de evaluación de impacto del CEES.

The metrics on the Lab4U application include the frequency and duration of each experiment, and

Figure 4 / Pilot Project and Teacher Training Timeline



Source: Lab4u Mexico Final Report (2018).

an analysis of each user's interaction (teacher or student). These indicators, displayed on a control panel, can be used as an independent evaluation as well as a means to corroborate the results obtained from the CEES impact assessment.

According to the Lab4U team, the indicators provide information about the (i) total number and percentage of active students and teachers; (ii) percentage of active users per school; (iii) percentage of active schools per month; (iv) total number of experiments performed per school; (v) number of times that a tool is used; (vi) number of times that an experiment is performed; (vii) number of events[3] in which a measurement is stored; (viii) number of events an experiment is completed; and (ix) total number of events.

PROCESS AND IMPACT EVALUATION

For the purpose of this project, process and impact assessments were considered essential, and were conducted by CEES. Since the intervention covered COBAES schools over August–December 2017 and the technology baccalaureates over January–May 2018, the impact assessment only included COBAES schools, given that the semester ended earlier, thus saving time.

Data collection for the measurement of the impact assessment was performed in two stages: baseline data (September) and follow-up data (December). Students and teachers alike were surveyed at each stage. Table 3 provides the structure of the questionnaire issued by CEES (EASE, 2018):

Table 3 / Structure of Questionnaire Administered by Mexico's Center for Educational and Social Studies

Section 1	Section2	Section 3	Section 4
• General student information, such as socioeconomic variables needed for analyzing results.	• Gathers the student´s opinion about physics with 32 reagents adapted to the subject of physics from the instrument published by Palacios et al. (2014).	• Measures the knowledge of physics topics covered by Lab4U experiments, considering expected learnings and skills according to the Physics I curriculum; • 20 multiple choice questions.	• A question to explore whether students have considered a career in science, technology, engineering, or mathematics; another question to assess their perception of the percentage of theory that a typical physics session contains.

Source: CEES (2018)

3
Events are user interactions with content, which can be independently monitored from a website or from an uploaded screen. Downloads, clicks on mobile phone ads, devices, Flash elements, embedded AJAX elements, and video viewings are all examples of actions that can be monitored as events.

The sample was drawn from 4,868 students in the fifth semester of the COBAES baccalaureate, 2,941 of whom were assigned to the treatment group and 1,927 to the control group. The average loss ratio[4] for the experiment is worth highlighting since it was 31.37 percent. This number is close to the school dropout rate added to the number of students who changed schools, recorded as official figures corresponding to the 2017/18 academic year in the three selected cities where the pilot project was conducted. In terms of the assessment, what is most relevant from this result is that the dropout rate was very similar between the treatment and control groups, suggesting that the project did not influence school dropout causes.

IMPACT INDICATORS

Does motivation play a fundamental role in the decision to drop out of high school?

Incorporating technology into the academic curriculum may be a means to stimulate student interest and participation in an area that has been traditionally uninteresting and has led to low acceptance levels.

The variables used to assess the impact of the project are therefore categorized into three groups: **(i)** self-concept (attitudes)[5] in physics; **(ii)** knowledge of the subject; and **(iii)** student interest in pursuing a STEM career. The following section summarizes the project's results for each of the variables and presents the conclusions.

4
This relates to the average number of students in the sample that CEES (responsible for the evaluation) lost contact with after they dropped out of school. The trial began with 4,868 students and only 3,330 remained.

5
This term refers to the perception that students have about their own abilities and competences to study physics.

3 RESULTS AND CONCLUSIONS

The conclusions presented in this section stem from the results obtained during two events. The first group derives from the CEES impact assessment and the second emanates from observations and externalities that arose during implementation.

IMPACT ASSESSMENT RESULTS

As previously indicated, the CEES impact assessment included COBAES baccalaureate students during the September–December 2017 semester.

In order to determine the impact of Lab4Physics on the students, a differential comparison was made, the data of which were gathered at the beginning and at the end of the project. Results for the three selected variables were compared **(attitudes/disposition toward physics, performance in the subject, and interest in STEM)**. The first comparison was between a group of students in the same grade who did not participate in the project (control group) and the group within the project (treatment group). The second comparison was between the total sample of students analyzed and the students in the treatment group who conducted more than three experiments.

Results are presented below in such a way as to reflect the impact of the experiment on each variable.

Improvement in student´s attitude/ disposition toward physics

The scale used sought to measure self-concept. Respondents expressed their level of agreement with four questions that referred to the self-perception of students on their ability and competence to study physics. By comparing those assigned to the treatment group with those assigned to the control group, an increase in self-concept of 0.11

For further details on the effects of this randomized controlled trial, please review the tables in the Annex section.

Go to Annexes

points was found for students exposed to Lab4U (Figure 5).

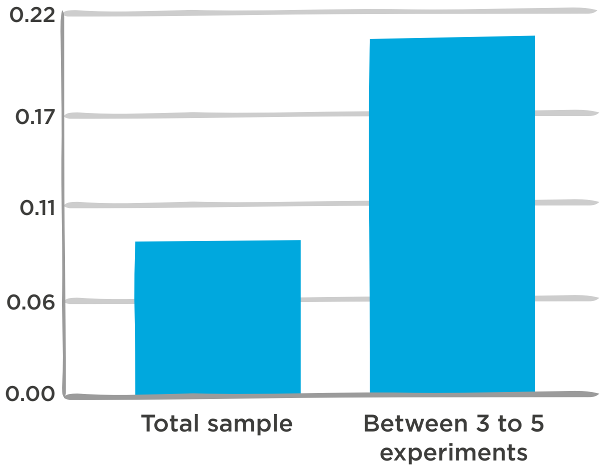
Figure 5 / Differences* in Self-Concept between Students Exposed and Not Exposed to Lab4U

*This is the difference between results obtained at the beginning and the end of the pilot project.

Source: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Education Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

By comparing this variable for both groups, it was found that students in the treatment group obtained better results (an increase of 0.8 points) in terms of self-concept (Figure 6).

Figure 6 / Differences in Self-Concept between Students Exposed to Three or More Experiments Compared with the Total Sample



Fuente: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Education Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

Improved performance in the covered area of knowledge

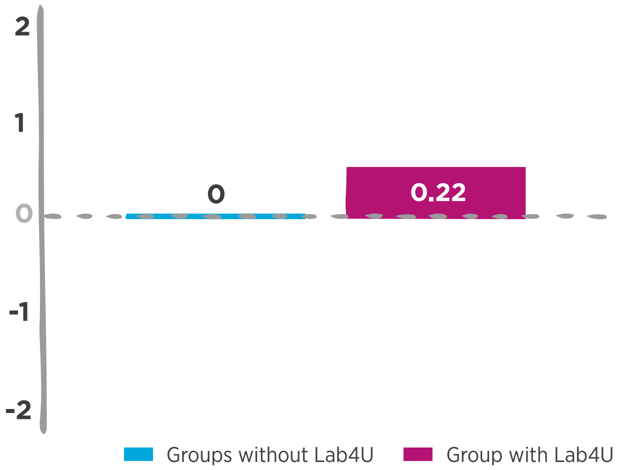
The knowledge of physics was measured by providing 20 questions on the contents covered by the experiments in the intervention. By comparing this variable for those in the treatment group with those in the control group, an increase of 0.22 points was found relating to the student knowledge of physics

Figure 5: The followings results were estimated using a difference means method, to complement the analysis of the effects please review the regressions presented in table A1 attached to this document. See Annexes

Figure 6: The followings results were estimated using a difference means method, to complement the analysis of the effects please review the regressions presented in tables A2 and A3 attached to this document See Annexes

in the first group, attributable to the use of Lab4U. The students in the control group did not record any change during the evaluation period (Figure 7).

Figure 7 / Differences in Performance in the Covered Area of Knowledge between Students Exposed and Not Exposed to Lab4U

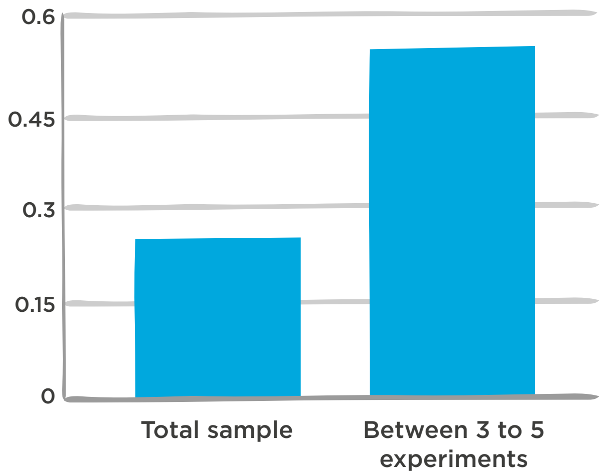


*This is the difference between results obtained at the beginning and the end of the pilot project.

Source: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Education Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

As in the case of the first impact variable, an additional comparison was added to the treatment group that performed over three experiments with the Lab4Physics application. By comparing this variable between the two groups, it was found that the students in the treatment group—who carried out or were exposed to more than three experiments—obtained superior results (an increase of 0.6 points) in their knowledge of physics, attributable to the use of the Lab4U tool (Figure 8).

Figure 8 / Differences in Performance in the Covered Area of Knowledge between Students Exposed to Three or More Experiments Compared with Total Sample



Source: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Education Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

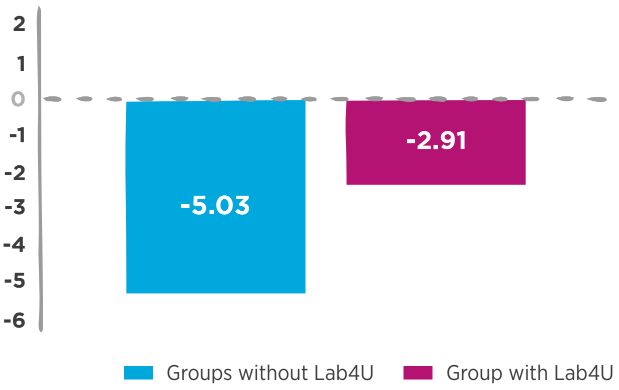
Figure 7: The followings results were estimated using a difference means method, to complement the analysis of the effects please review the regressions presented in table A4 attached to this document. *See Annexes*

Figure 8: The followings results were estimated using a difference means method, to complement the analysis of the effects please review the regressions presented in tables A5 and A6 attached to this document. *See Annexes*

Increase in the number of students interested in STEM careers

Interest in STEM careers was recorded from responses to the baseline and in a follow-up survey. By comparing this variable among the treatment and control groups, a difference of 2.12 points was observed among students who used Lab4U (Figure 9).

Figure 9 / Differences in the Level of Interest of Studying a STEM Career among Students Exposed and Not Exposed to Lab4U

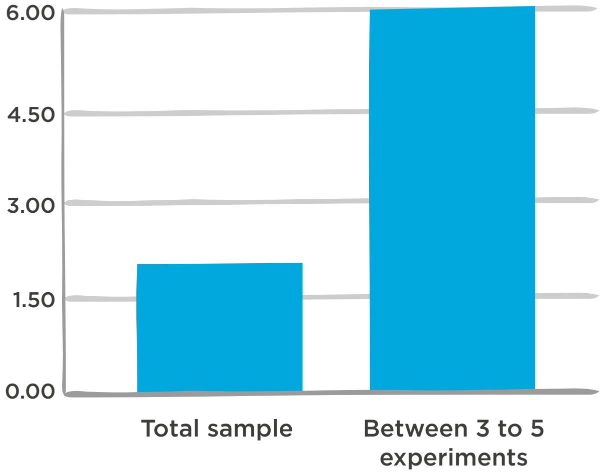


*This is the difference between results obtained at the beginning and the end of the pilot project.

Source: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Education Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

Similarly, by comparing this variable for both groups, the findings were that students in the treatment group, who performed or were exposed to three or more experiments, obtained higher scores (an increase of 3.68 points) in their level of interest of studying a STEM career (Figure 10).

Figure 10 / Differences in the Level of Interest of Studying a STEM Career among Students Exposed to Three or More Experiments versus the Total Sample



Source: Author's elaboration with data from the Lab4U impact assessment on upper school education student learning and attitudes in Sinaloa, Mexico, prepared by Support Strategies and Education Services (Estrategias de Acompañamiento y Servicios Educativos, or EASE).

Figure 9: The followings results were estimated using a difference means method, to complement the analysis of the effects please review the regressions presented in table A7 attached to this document. *See Annexes*

Figure 10: The followings results were estimated using a difference means method, to complement the analysis of the effects please review the regressions presented in tables A8 and A9 attached to this document. *See Annexes*

Based on the interaction of COBAES students with the Lab4Physics mobile application during a three-month period, the following conclusions are drawn:

1. The group of students exposed to the Lab4Physics application (treatment group) shows an increase in each impact variable compared with the group who did not receive the intervention.

2. Prolonged exposure (more than three experiments) to the use of the Lab4Physics application in the classroom shows incremental and positive results when compared with its limited use. This conclusion was reached after comparing results with the students in the treatment group who were exposed to over three experiments during the assessed school semester.

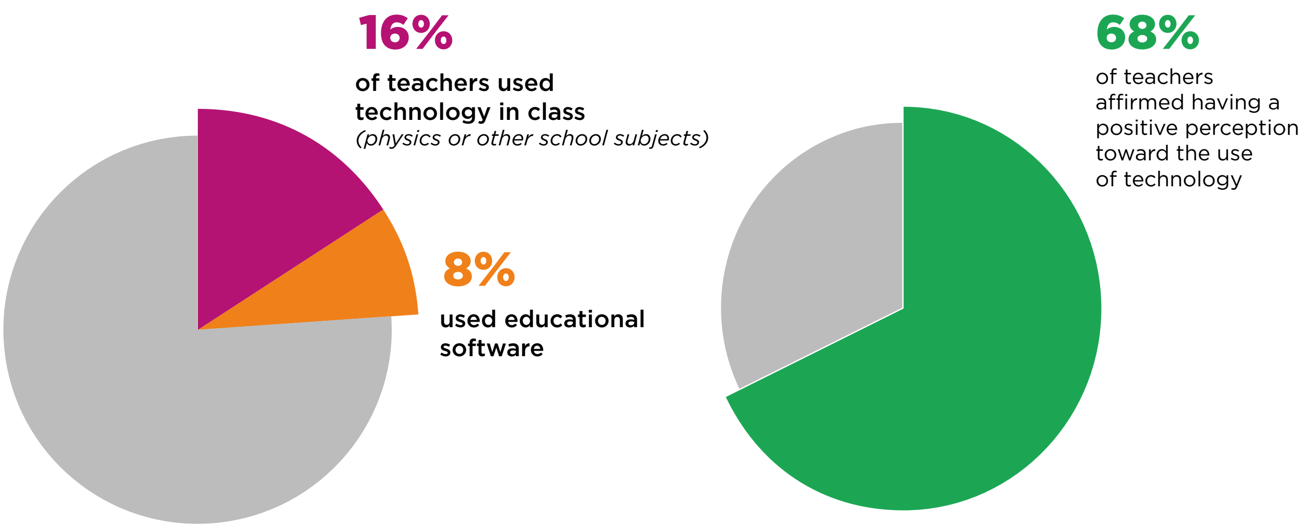
3. Lab4U, through its Lab4Physics application, helps increase academic performance in physics by improving the self-concept of students on their knowledge of the subject.

4. Lab4U, through its Lab4Physics application, succeeded in enhancing the interest of users to study for a STEM career.

OBSERVATIONS AND EXTERNALITIES

During the intervention, the development of partnerships was observed among teachers and educational authorities and/or students and the Lab4U team. The shared learning that emerged from this growing community of practice—between teachers from different schools and cities of the State of Sinaloa—and the training and support provided by the Lab4U team (on-site or online) were crucial for generating a change in the perception of teachers about specific issues: the use of technology in general in the classroom and the positive perception of using Lab4U to support lessons in physics.

Figure 11 / Teacher Perspectives about the Technology, Before and After, with the Number of Teachers Who Participated in Training Sessions

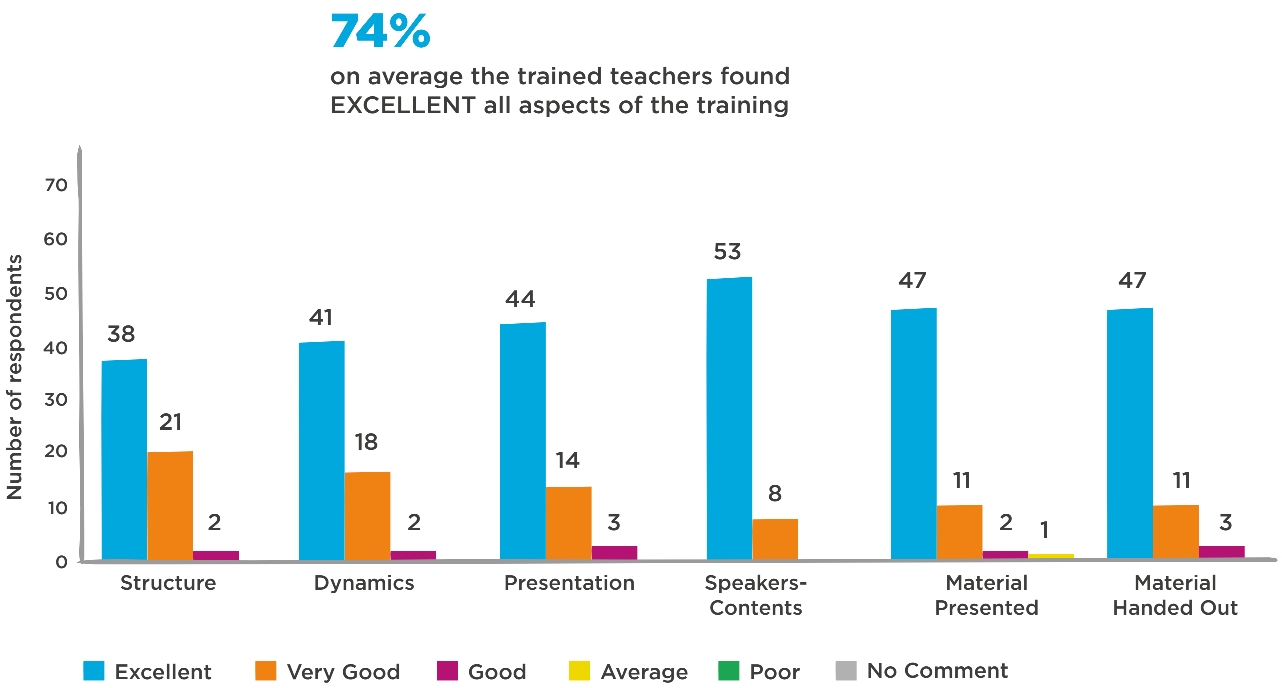


Source: Prepared on the basis of the Lab4U full-day advanced training report.

The surveys conducted by the CEES team show that, previous to the intervention, 16 percent of teachers used technology in class (physics or other school subjects) and only 8 percent used educational software. The follow-up surveys performed during the intervention show that, after the project, 68 percent of teachers affirmed having a positive perception toward the use of the technology.

Similarly, the follow-up survey performed after the completion of on-site teacher-training showed that 74 percent of those trained in Lab4U rated the various aspects of the training as excellent (Figure 12).

Figure 12 / Teacher Perception of Training Delivered by Lab4U



Source: Prepared on the basis of the Lab4U full-day advanced training report.

4

LESSONS LEARNED AND RECOMMENDATIONS FOR FUTURE SCALABILITY

This section summarizes the lessons learned and the recommendations arising from the intervention. It will also inform future projects of the same scale in terms of the (i) technology gap; (ii) teacher training; (iii) strengthening of the educational microsystem; and (iv) exposure to Lab4Physics experiments.

1 Technology Gap. While it is true that Internet and mobile phone penetration in Latin America continues to rise exponentially, and that by 2020 it is estimated that 71 percent of the region´s population will own a smartphone (an increase of 12 percent since 2017) (GSMA, 2017), in this pilot project, the Internet access that students had in order to easily use the application varied. Also, it should be noted that while most students had access to a smartphone, the connectivity and memory storage on their phones was limited for installing this type of application.

Lab4U adopted two sensible strategies to sustain the participation of users: working in teams of two-to-three students and developing an offline version of the application. This last strategy was useful for students to use the technology without the need of having an internet connection.

In any case, Internet connectivity is essential for downloading the application and it is therefore recommended that schools receiving the intervention make an area available for students to easily download the technology onto their mobile phones. This can be accomplished in several ways, whether by sharing the school network with students during the intervention or by forming strategic alliances with technology and mobile network companies.

2 Teacher Training. The profile of teachers and students was diverse. Unlike the students, not all teachers were familiar with the technology. This was compensated by the organization of training sessions, with a full-day advanced session carried out in the middle of the semester in order to reinforce the digital competencies of teachers and to clarify doubts regarding the content.

It is worth noting that the success of these training sessions was due to the strengthening and monitoring skills on the part of the Lab4U team and the support of Sinaloa´s education authorities, who paid teachers for the hours of training and understood the importance of

providing a learning space to foster project viability and continuity.

With regard to the scalability of this effort, a mapping of the digital capabilities of teachers is recommended. This would offer an overview of teacher growth and training opportunities to later promote communities of practice and collaboration which, in turn, will create incentives to use the technology for students.

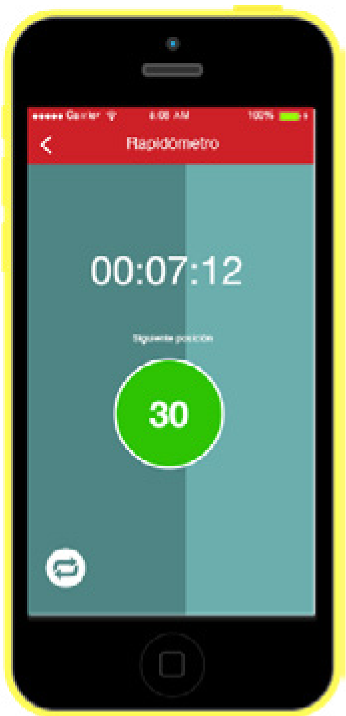
For educators, the real challenge lies in going beyond perceiving technology as a tool or as a set of "educational platforms equipped with information technology". Rather, they must focus on how to strengthen the skills and confidence of students to excel online and in real life in a world were digital media are omnipresent (Pombo, Gupta, and Stankovic, 2018).

When teachers collaborate, they are able to discuss and share ideas for better meeting the needs of students with commonalities (such as the grade they are in or their level of capacity). In this way, they can create strategies that help every teacher become as effective as possible in improving their teaching. Team work among teachers raises the quality and effectiveness of education by providing a range of professional perspectives and encouraging dialogue and discussion (Wagner, 2012).

3 Strengthening of the Educational Microsystem. It is necessary to discuss collaboration opportunities between the different influencing agents on students: teachers, educational authorities, peers, the community, and the family. Student performance increases when the teaching environment improves. Student perceptions about the educational environment are important. With this in mind, schools much take advantage of the passion and interests of their students, help them develop critical skills and advantages that may be decisive in life, and guide them toward the path for real progress, thus leading them to success (Wagner, 2015).

With regard to the educational authorities, there was evidence during the intervention of the need for their commitment and promotion of the project to managers and teachers alike, a factor that was crucial in motivating attendance and participation during project implementation. By including teachers from the onset (direct operators of the intervention), this allowed having partners in the field who would internalize and share the benefits of the project.

In the future, efforts must also include creating spaces in schools to encourage the exchange of knowledge acquired from the use of the application. In terms of scale, this could take place collectively among current users and other students (peers) whose proximity in the community would enable them to experience a Lab4Physics application. This would eventually produce enthusiasm among potential users, motivating them to request the tool for their own schools.



4 Exposure to Lab4Physics experiments. Getting all users to complete a minimum number of experiments is of utmost importance to ensure that they obtain a minimum dose of the intervention. The main results of the impact assessment performed by CEES suggest that when participants received a relatively high dose (defined as being exposed to at least three to ten experiments), the intervention appeared to have had a positive and significant effect on the three impact variables evaluated: self-concept relative to physics, academic performance in the subject matter, and an obvious interest in pursuing a STEM career.

The number of experiments completed may be related to the alignment between teachers` planning and the project's implementation. It is possible that in the case of COBAES—especially when teachers joined the project—the curriculum for the school cycle had been already drafted. If the use of the Lab4Physics application is considered a reinforcing component of activities in curricular planning, it is more likely that teachers will adopt the initiative (EASE, 2018).

These four project scalability elements will reinforce the success of the Inter-American Development Bank and Lab4U in their intervention in Sinaloa. The importance of integrating the technology with the support of educational leaders, as well as providing teacher training, should be emphasized. This will not only ensure solid integration into curricular programs but will also strengthen the efforts of the teaching and learning of physics so as to prepare students for their entry into an increasingly competitive job market.

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ANNEXES

Annex 1: Regressions – Self-concept in physics (entire sample)

VARIABLES	(1) SELF-CONCEPT	(2) SELF-CONCEPT	(3) SELF-CONCEPT	(4) SELF-CONCEPT	(5) SELF-CONCEPT
TREATMENT	0.0869	0.0794	0.0700	0.0647	0.0715
	(0.0828)	(0.0724)	(0.0712)	(0.0739)	(0.0717)
SELFCONCEPT_LB		0.399***	0.398***	0.398***	0.399***
		(0.0197)	(0.0192)	(0.0193)	(0.0193)
LOS MOCHIS			-0.00618	-0.00644	-0.0116
			(0.0733)	(0.0730)	(0.0747)
CULIACÁN			-0.0297	-0.0252	-0.0243
			(0.0685)	(0.0703)	(0.0699)
SCHOOL SHIFT (MORNING)				0.0994	0.101
				(0.0888)	(0.0876)
GROUND FLOOR/ CEMENT					-0.0264
					(0.0454)
Constant	7.014***	4.171***	4.194***	4.102***	4.103***
	(0.0707)	(0.152)	(0.138)	(0.133)	(0.133)
Observations	3,088	2,893	2,893	2,893	2,858
R-squared	0.001	0.157	0.157	0.157	0.158

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 2: Regressions - Self-concept in physics by intensity of treatment

VARIABLES	6 to 10 exp SELF-CONCEPT	7 to 10 exp SELF-CONCEPT	8 to 10 exp SELF-CONCEPT	9 to 10 exp SELF-CONCEPT	10 exp SELF-CONCEPT
TREATMENT	0.158**	0.187*	0.119	0.173	0.147
	(0.0779)	(0.0958)	(0.0989)	(0.108)	(0.108)
SELFCONCEPT_LB	0.432***	0.423***	0.421***	0.424***	0.439***
	(0.0259)	(0.0283)	(0.0287)	(0.0285)	(0.0263)
LOS MOCHIS	0.117	0.121	0.100	0.0987	0.0802
	(0.104)	(0.122)	(0.112)	(0.100)	(0.0904)
CULIACÁN	0.0111	0.0150	-0.0292	-0.0571	-0.0807
	(0.103)	(0.118)	(0.108)	(0.0988)	(0.0921)
SCHOOL SHIFT (MORNING)	0.0691	0.0798	0.0670	0.0577	0.0480
	(0.0933)	(0.0983)	(0.0993)	(0.100)	(0.101)
GROUND FLOOR/ CEMENT	-0.0105	-0.00903	0.00515	-0.0150	-0.0123
	(0.0615)	(0.0670)	(0.0704)	(0.0745)	(0.0755)
Constant	3.829***	3.886***	3.935***	3.953***	3.870***
	(0.189)	(0.207)	(0.205)	(0.198)	(0.180)
Observations	1,633	1,489	1,397	1,329	1,313
R-squared	0.175	0.169	0.164	0.167	0.176

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 3: Regressions - Self-concept in physics by intensity of treatment (continued)

VARIABLES	6 to 10 exp SELF-CONCEPT	7 to 10 exp SELF-CONCEPT	8 to 10 exp SELF-CONCEPT	9 to 10 exp SELF-CONCEPT	10 exp SELF-CONCEPT
TREATMENT	0.158**	0.187*	0.119	0.173	0.147
	(0.0779)	(0.0958)	(0.0989)	(0.108)	(0.108)
SELFCONCEPT_LB	0.432***	0.423***	0.421***	0.424***	0.439***
	(0.0259)	(0.0283)	(0.0287)	(0.0285)	(0.0263)
LOS MOCHIS	0.117	0.121	0.100	0.0987	0.0802
	(0.104)	(0.122)	(0.112)	(0.100)	(0.0904)
CULIACÁN	0.0111	0.0150	-0.0292	-0.0571	-0.0807
	(0.103)	(0.118)	(0.108)	(0.0988)	(0.0921)
SCHOOL SHIFT (MORNING)	0.0691	0.0798	0.0670	0.0577	0.0480
	(0.0933)	(0.0983)	(0.0993)	(0.100)	(0.101)
GROUND FLOOR/ CEMENT	-0.0105	-0.00903	0.00515	-0.0150	-0.0123
	(0.0615)	(0.0670)	(0.0704)	(0.0745)	(0.0755)
Constant	3.829***	3.886***	3.935***	3.953***	3.870***
	(0.189)	(0.207)	(0.205)	(0.198)	(0.180)
Observations	1,633	1,489	1,397	1,329	1,313
R-squared	0.175	0.169	0.164	0.167	0.176

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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Annex 4: Regressions – Knowledge in physics (entire sample)

VARIABLES	(1) KNOWLEDGE	(2) KNOWLEDGE	(3) KNOWLEDGE	(4) KNOWLEDGE	(5) KNOWLEDGE
TREATMENT	0.252	0.243	0.174	0.170	0.148
	(0.208)	(0.191)	(0.167)	(0.173)	(0.171)
KNOWLEDGE _LB		0.274***	0.273***	0.272***	0.270***
		(0.0284)	(0.0288)	(0.0287)	(0.0281)
LOS MOCHIS			0.0567	0.0565	0.0440
			(0.227)	(0.227)	(0.225)
CULIACÁN			-0.170	-0.167	-0.184
			(0.166)	(0.171)	(0.167)
SCHOOL SHIFT (MORNING)				0.0646	0.0725
				(0.213)	(0.209)
GROUND FLOOR/ CEMENT					0.0521
					(0.107)
Constant	7.475***	5.425***	5.530***	5.469***	5.489***
	(0.143)	(0.157)	(0.235)	(0.340)	(0.336)
Observations	3,330	3,330	3,330	3,330	3,278
R-squared	0.002	0.072	0.073	0.073	0.072

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 5: Regressions - Knowledge in physics by intensity of treatment

VARIABLES	1 to 10 exp KNOWLEDGE	2 to 10 exp KNOWLEDGE	3 to 10 exp KNOWLEDGE	4 to 10 exp KNOWLEDGE	5 to 10 exp KNOWLEDGE
TREATMENT	0.382**	0.432**	0.438**	0.485**	0.411**
	(0.183)	(0.195)	(0.197)	(0.201)	(0.202)
KNOWLEDGE_LB	0.284***	0.281***	0.278***	0.280***	0.271***
	(0.0326)	(0.0333)	(0.0339)	(0.0354)	(0.0371)
MOCHIS	0.324	0.337	0.351	0.265	0.145
	(0.239)	(0.264)	(0.260)	(0.261)	(0.247)
CULIACÁN	0.0660	0.0416	0.0613	0.0580	0.0113
	(0.173)	(0.179)	(0.179)	(0.195)	(0.195)
SCHOOL SHIFT (MORNING)	0.0784	0.0703	0.0749	0.0946	0.116
	(0.216)	(0.218)	(0.219)	(0.221)	(0.222)
GROUND FLOOR/ CEMENT	0.142	0.115	0.123	0.141	0.107
	(0.115)	(0.117)	(0.120)	(0.120)	(0.116)
Constant	5.110***	5.162***	5.167***	5.150***	5.271***
	(0.387)	(0.395)	(0.402)	(0.418)	(0.428)
Observations	2,434	2,353	2,273	2,126	1,988
R-squared	0.088	0.088	0.086	0.088	0.079

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 6: Regressions - Knowledge in physics by intensity of treatment (continued)

VARIABLES	6 to 10 exp KNOWLEDGE	7 to 10 exp KNOWLEDGE	8 to 10 exp KNOWLEDGE	9 to 10 exp KNOWLEDGE	10 exp KNOWLEDGE
TREATMENT	0.384*	0.438*	0.431*	0.480*	0.410
	(0.218)	(0.225)	(0.246)	(0.261)	(0.255)
KNOWLEDGE_LB	0.274***	0.266***	0.264***	0.268***	0.265***
	(0.0399)	(0.0410)	(0.0431)	(0.0450)	(0.0446)
MOCHIS	0.178	0.211	0.229	0.149	0.152
	(0.247)	(0.219)	(0.228)	(0.186)	(0.182)
CULIACÁN	0.0716	0.0317	-0.00906	-0.0677	-0.108
	(0.202)	(0.207)	(0.207)	(0.192)	(0.195)
SCHOOL SHIFT (MORNING)	0.135	0.127	0.105	0.110	0.0965
	(0.225)	(0.238)	(0.240)	(0.243)	(0.244)
GROUND FLOOR/ CEMENT	0.0579	0.0362	0.0458	-0.0138	-0.0252
	(0.116)	(0.121)	(0.125)	(0.122)	(0.124)
Constant	5.200***	5.293***	5.344***	5.391***	5.455***
	(0.450)	(0.473)	(0.489)	(0.508)	(0.506)
Observations	1,869	1,711	1,609	1,536	1,517
R-squared	0.079	0.075	0.074	0.077	0.076

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 7: Regressions – Students interested in pursuing STEM careers (entire sample)

VARIABLES	(1) STEM	(2) STEM	(3) STEM	(4) STEM	(5) STEM
TREATMENT	0.0200	0.0174	0.0225	0.0237	0.0247
	(0.0275)	(0.0234)	(0.0231)	(0.0238)	(0.0237)
STEM_LB		0.324***	0.325***	0.326***	0.323***
		(0.0218)	(0.0214)	(0.0213)	(0.0209)
LOS MOCHIS			-0.0389	-0.0388	-0.0439*
			(0.0264)	(0.0264)	(0.0260)
CULIACÁN			-0.00519	-0.00624	-0.00283
			(0.0263)	(0.0267)	(0.0264)
SCHOOL SHIFT (MORNING)				-0.0227	-0.0224
				(0.0379)	(0.0377)
GROUND FLOOR/ CEMENT					0.0274*
					(0.0137)
Constant	0.319***	0.198***	0.212***	0.233***	0.223***
	(0.0229)	(0.0206)	(0.0254)	(0.0466)	(0.0454)
Observations	3,180	3,050	3,050	3,050	3,009
R-squared	0.000	0.112	0.113	0.113	0.113

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 8: Regressions - Students interested in pursuing STEM careers by intensity of treatment

VARIABLES	1 to 10 exp STEM	2 to 10 exp STEM	3 to 10 exp STEM	4 to 10 exp STEM	5 to 10 exp STEM
TREATMENT	0.0439*	0.0485*	0.0495*	0.0534**	0.0583**
	(0.0236)	(0.0243)	(0.0250)	(0.0257)	(0.0259)
STEM_LB	0.334***	0.334***	0.332***	0.334***	0.326***
	(0.0271)	(0.0258)	(0.0258)	(0.0264)	(0.0276)
MOCHIS	-0.0415	-0.0428	-0.0433	-0.0505	-0.0481
	(0.0266)	(0.0291)	(0.0309)	(0.0341)	(0.0346)
CULIACÁN	-0.0153	-0.0212	-0.0183	-0.0292	-0.0379
	(0.0256)	(0.0267)	(0.0287)	(0.0303)	(0.0300)
SCHOOL SHIFT (MORNING)	-0.0297	-0.0311	-0.0302	-0.0322	-0.0360
	(0.0371)	(0.0370)	(0.0371)	(0.0369)	(0.0370)
GROUND FLOOR/ CEMENT	0.0330*	0.0285*	0.0341*	0.0310	0.0354*
	(0.0167)	(0.0168)	(0.0176)	(0.0189)	(0.0206)
Constant	0.231***	0.238***	0.234***	0.245***	0.255***
	(0.0438)	(0.0447)	(0.0459)	(0.0465)	(0.0465)
Observations	2,249	2,171	2,102	1,960	1,827
R-squared	0.122	0.122	0.121	0.121	0.118

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Annex 9: Regressions - Students interested in pursuing STEM careers by intensity of treatment (continued)

VARIABLES	6 to 10 exp STEM	7 to 10 exp STEM	8 to 10 exp STEM	9 to 10 exp STEM	10 exp STEM
TREATMENT	0.0495*	0.0511	0.0560*	0.0939***	0.0922**
	(0.0281)	(0.0312)	(0.0281)	(0.0341)	(0.0364)
STEM_LB	0.312***	0.313***	0.312***	0.311***	0.309***
	(0.0292)	(0.0304)	(0.0323)	(0.0330)	(0.0336)
MOCHIS	-0.0330	-0.0254	-0.0245	-0.0214	-0.0187
	(0.0355)	(0.0404)	(0.0393)	(0.0384)	(0.0394)
CULIACÁN	-0.0253	-0.0196	-0.0135	-0.00676	-0.00531
	(0.0307)	(0.0360)	(0.0345)	(0.0336)	(0.0350)
SCHOOL SHIFT (MORNING)	-0.0341	-0.0283	-0.0260	-0.0240	-0.0239
	(0.0375)	(0.0383)	(0.0384)	(0.0386)	(0.0388)
GROUND FLOOR/ CEMENT	0.0376*	0.0316	0.0321	0.0306	0.0306
	(0.0214)	(0.0210)	(0.0221)	(0.0232)	(0.0232)
Constant	0.245***	0.236***	0.230***	0.224***	0.223***
	(0.0474)	(0.0491)	(0.0477)	(0.0467)	(0.0474)
Observations	1,715	1,563	1,468	1,398	1,381
R-squared	0.108	0.107	0.107	0.109	0.107
Robust standard errors in parentheses					
*** p<0.01, ** p<0.05, * p<0.1					

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This case study stems from *Graduate XXI*, the IDB's initiative to seek innovative and digital solutions for young Latin Americans at risk of dropping out of school, an initiative dreamed and executed by Marcelo Cabrol.

Results, both of impact and processes, are showcased in this document with the purpose of presenting learning opportunities that can serve as inspiration for future projects and collaborations amongst innovators from the region and their respective startups.

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“WHAT IS THIS FOR?”

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