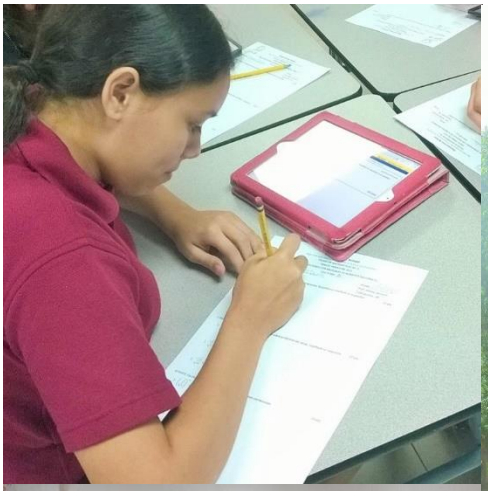


ASSISTING PANAMANIAN EDUCATION

Using the online learning tool, ASSISTments, to improve math education in Panama

By: Alex Gikas, Jennifer Golden,
Casey Kracinovich, Jose Spiegel

Autoridad Nacional para la Innovación Gubernamental

WPI

ASSISTing Panamanian Education:

Using the online learning tool, ASSISTments, to improve math education in Panama

An interactive Qualifying Project submitted to the faculty of WORCESTER POLYTCHNIC INSTITUTE in partial fulfillment of the requirements for the degree of Bachelor of Science

Submitted By:

Alex Gikas

Jennifer Golden

Casey Kracinovich

Jose Spiegel

Submitted On:

October 26, 2015

Sponsoring Agency:

Autoridad Nacional para la Innovación Gubernamental

Project Advisors:

Professor Thomas B. Robertson

Autoridad Nacional para la Innovación Gubernamental

WPI

Abstract

Globally, poor education in developing countries is both a symptom of, and helps perpetuate, poverty. Because of limited resources, government turnover, and socioeconomic inequality, Panamanian math education is weak, scoring poorly on global standardized tests, even when compared to neighboring countries with similar investment in education. Educators are exploring educational technology as a potential solution to educational difficulties in the developing world, but experience many challenges. We worked alongside the Autoridad Nacional para la Innovacion Gubernamental to determine if incorporating educational technology, such as the feedback-based website, ASSISTments, into Panamanian math classes would improve test scores, student engagement, and teaching efficiency. To evaluate the potential of ASSISTments in Panama, we performed a trial with a local private school, and conducted surveys and interviews with students, teachers, and government officials. Though the students who used ASSISTments improved their test scores and reacted positively, our results are ultimately inconclusive because of trial limitations, such as time. We recommend a more extensive trial to validate our results.

Acknowledgements

We would like to thank the following organizations and people for their contributions:

Autoridad Nacional para la Innovacion Gubernamental

Irvin Halman

Fabricio Fletcher

Jorge Alcazar

Anabael Broce

Panamerican School

Johnny Serracin

Jonathan Powell

WPI

Professor Tahar El-Korchi

Professor Thomas B. Robertson

Professor Aaron Sakulich

MEDUCA

SENACYT

Executive Summary

A 2010 survey found that 95% of Panamanian teachers consider math to be the subject that their students struggle with most (Valderrama Bahamóndez & Schmidt, 2010). Panamanian math education is weak, scoring poorly on international standardized tests both globally and as compared to neighboring countries with similar investment in education, such as Colombia (OECD 2009, LLECE 2014). Studies show that Panamanian math students struggle with basic skills such as the multiplication table and the four basic arithmetic operations (Valderrama Bahamóndez & Schmidt, 2010). Likely explanations for Panama's problems with math education include socio-economic inequality, limited funding and resources, and government turnover.

Many educators are exploring educational technology as a potential solution to improve learning in the developing world. Large scale meta-studies demonstrate that under ideal conditions, educational technologies can have a positive impact on student performance in the developed world (Means et al., 2009, Cheung & Slavin, 2013). Many obstacles arise when implementing educational technologies in developing countries, such as limited equipment, misunderstandings of technology, and economic feasibility (Woolf, Arroyo, & Zualkernan, 2011). In order to be successful in Panama, educational technologies must be affordable, accessible, and practical.

ASSISTments is an educational website that specializes in math and has shown promising results in the United States. It helps students work through problems, and provides teachers with immediate feedback on student performance. ASSISTments was originally geared towards middle school math standardized test preparation, but it has now expanded to include other subjects such as statistics, science, and chemistry. Because ASSISTments is free and accessible on any device with internet access, it could be used in the developing world.

Project Goal, Research Questions, and Methodology

We worked alongside the Autoridad Nacional para la Innovacion Gubernamental (see Appendix A for more information) to determine if incorporating educational technology for math, such as ASSISTments, into Panamanian schools will improve test scores, student engagement, and teaching efficiency. To accomplish our goal, we defined four research objectives:

1. Assess the state of middle school math education in Panama.
2. Assess Panamanian experiences and attitudes concerning educational technology.
3. Develop a feasible, efficient, and scientific trial to test ASSISTments in a Panamanian middle school.

4. Analyze the results of the ASSISTments trial through both test scores and student/teacher opinion.

To obtain information, opinions, and experiences on the state of math education and use of educational technologies in Panama, we conducted surveys and interviews. We surveyed middle school students at a local private school, and math teachers across Panama. We interviewed government officials with the Ministry of Education and two local private school teachers. With the collaborative data and research on educational experiments, our team designed a trial to test ASSISTments in the Panamerican School. We worked with a seventh-grade class, splitting it into a control section and an experimental section. The experimental section used ASSISTments in class for short classworks on six days and a long class assignment on one day. The control section did identical assignments on paper. Before and after the trial, we interviewed the teachers and surveyed the students.

Findings and Analysis

Our findings are divided into four sections based on our objectives.

Objective 1: Assess the state of middle school math education in Panama.

Finding 1: Because most teachers, particularly in primary school, have received inadequate training, they generally teach using "old-fashioned" methods focusing on rote memorization, thus undermining students' basic skills, retention levels, math applications and analysis skills, and test performance.

Primary school teachers in Panama are only required to complete high school, with a specialized teaching diploma. Since primary school teachers are often not specially trained to teach math, students often do not learn math basics at a young age. Many of the people that we interviewed described Panamanian education as "old-fashioned." Instructors teach in the same way that they were taught, with an emphasis on rote memorization rather than analysis and critical thinking. Ideally, ASSISTments and the feedback that it provides could help turn teaching into a two-way process. Also, ASSISTments hints could help students to work through analysis problems.

Finding 2: Most Panamanian students find math to be particularly difficult, as shown by our surveys and confirmed by a more widespread survey.

80% of the 100 middle school students that we surveyed rated the difficulty of math to be 3 or higher on a scale from 1 (very easy) to 5 (very difficult). Most of these students (56%) chose math as their most difficult subject. A more widespread survey found that 44% of Panamanian students find math to be their most difficult subject (Valderrama Bahamóndez & Schmidt, 2010).

Objective 2: Assess Panamanian experiences and attitudes concerning educational technology.

Finding 1: Some Panamanian public and private schools have attempted to implement educational technologies such as Smartboards, Balboa Laptops, and Destino Matematico, but most have ultimately failed because of insufficient teacher training and frustrations such as losing a significant amount of class time to setting up the technology.

Panama has attempted to introduce several educational technologies such as Balboa Laptops, Smartboards, Schoology, Destino Matematico, and Khan Academy. From these experiences, four common problems arose:

1. Truncated programs: Due to government turnover, many programs are begun but not completed.
2. Overuse of class time: Classes in Panama are short, sometimes only 30-45 minutes. Teachers found that time taken for setting up computers and connecting to wireless internet for an online assignment could be up to half of the class time.
3. Insufficient training: Often, teachers did not receive enough training and thus did not fully understand the technology and how to efficiently use it.
4. Insufficient support: Programs instituted by the government often lacked significant support. As a result, teachers sometimes encountered frustrations such as technical bugs, and abandoned the technologies as a result.

Understanding these experiences helped us avoid the same problems in the ASSISTments trial. We provided substantial teacher training before the trial and support throughout the trial to avoid making the same mistakes.

Finding 2: Of the 100 seventh- and eighth- grade private school students that we surveyed, nearly all of them would be willing to try an educational technology.

Students appear to be enthusiastic towards using educational technology. Students who have already used educational technology likely had a positive experience with it because they are interested in using it again.

Objective 3: Develop a feasible, efficient, and scientific trial to test ASSISTments in a Panamanian middle school.

Finding 1: Rather than a true experimental design that is neither feasible nor ideal (due to randomized groups), a quasi-experimental design in which non-random control and experimental groups drawn from pre-existing classes are given identical pretests and posttests is the most feasible trial design.

According to the quasi-experimental design, both groups are observed and tested prior to the start of the trial. The experimental group goes through the program, and the control group does not. Afterwards both are again given identical tests. The results of the tests can then be compared to show the effects of the program. The true experimental design is identical to the quasi-experimental design

except that the control and experimental groups must be random. We had to use nonrandom pre-existing classes as our control and experimental groups, so the true experimental design was not feasible for our trial.

Objective 4: Analyze the implementation of ASSISTments in schools, as shown through both test scores and student/teacher opinions.

Finding 1: After using ASSISTments, average student test scores were 10% better than the class average of all tests taken in the previous trimester, whereas the control section saw no significant improvement.

The experimental section saw more improvement in grades than the control section. On the pretest, both sections performed the same, proving that they had identical prior knowledge on the topic. On the posttest, the experimental section averaged 4.1 (of 5), while the control section averaged only 3.6 (of 5). Without considering our limitations, it appears as though ASSISTments did show potential as a possible solution to increasing student math performance.

Finding 2: The teacher believes that ASSISTments increased his time efficiency and has such a strong positive opinion that he is already using it in his other class sections.

The teacher believes that the program was not a large investment of time to learn and did increase the efficiency of his class. Because time efficiency was difficult to measure, we obtained his general opinions on ASSISTments as well. He thought that the ASSISTments feedback was valuable to teaching. He also thought that ASSISTments would be useful in any school that has the necessary facilities for it.

Finding 3: The majority of students believed that ASSISTments was a useful tool that increased their engagement in math class, and all of them thought that other students would like using it.

Based on student opinions drawn from our survey, according to 86% of students, ASSISTments was more engaging than traditional paper classwork. Conversely, the teacher believed that students were no more interested and engaged in their classwork than normal when using the program. When asked to rank ASSISTments usefulness on a scale from 1 to 5 (most useful) 86% of students ranked ASSISTments at a 4 or 5. All students would recommend ASSISTments to students in other classes and schools.

Trial Analysis and Conclusions:

While student test scores did improve, and both students and teachers had positive opinions on ASSISTments, many limitations make us question the validity of our trial. These are:

1. **Class topic**

We only tested one class topic. It is entirely possible that ASSISTments could have been more or less useful for other topics. It is also possible that the experimental section grasped the concept of radicals more easily than the control section, regardless of ASSISTments. Testing a wider range of topics would better validate the effect of ASSISTments on grades.

2. **Feedback/trial set-up**

   The teacher understood the benefits of the ASSISTments feedback, but did not use the feedback, a major feature of ASSISTments, to its full potential. This was largely because the set-up of the trial in his specific class did not allow for enough in-class reviews of ASSISTments assignments. Our trial was too short to be able to include more assignments, and thus more in-class review would allow for the feedback to be used to its full potential.

3. **Change in routine**

   Related to new methods of learning: Students may have been influenced by the change of their everyday learning routine. A new routine may have been more engaging, thus increasing student focus and learning.

   Related to our presence: Students may have been influenced by our presence in their classrooms. This may have affected their behavior, class performance, or their interest in ASSISTments.

4. **Computers**

   When talking to students after the trial, many said that they enjoyed using computers in classrooms. This led us to question whether their improved test scores were specific to ASSISTments. It is possible that the use of any computer program would have caught students' attention, thus showing improvement in test scores and positive opinions.

5. **Sample size**

   Only one class of 24 students used ASSISTments, making our sample size small and uniform. We only worked with one teacher. Our results cannot be generalized for all Panamanian schools. Other students and teachers may have reacted differently to ASSISTments.

Many of these limitations were inevitable because of the two week time frame. We cannot say for sure that the increase in student test scores or the positive reception to ASSISTments was entirely due to ASSISTments and not one of these many other influences. Ultimately, our trial is inconclusive because of our various limitations.

Recommendations

Recommendations for ASSISTments creators:

1. **To make ASSISTments an appealing program to more schools, especially those in the developing world, we recommend the website creators consider the following changes to the program:**

a. General changes
    i. A space for students to include their scratch work.
    ii. An option for weighted grading.
    iii. The ability for students to message/chat their teachers.
    iv. The option for a time limit for assignments to be completed.
    v. A more user-friendly builder tab.
b. Specific to developing countries
    i. The option of non-US time zones.
    ii. A version that is available offline.
    iii. The option for languages other than English.
    iv. Organize content by topics rather than U.S. Curriculum.

Recommendations for follow-up projects:

1. **We recommend that the Panamanian government (AIG, SENACYT, or MEDUCA) replicate our trial, taking steps to avoid the variables that we encountered such as sample size limitations and time constraints.**

Because our trial showed improvement in student test scores, but had numerous limitations, we recommend that ASSISTments is tested more thoroughly with a similar trial to validate our findings, making the following extra considerations:

a. Choose teachers who vary in computer competence
b. Spend more time in class and lengthen the trial
c. Cover more topics
d. Use experimental and control class sections that are even in behavior, schedule, and academics
e. Increase the use of ASSISTments feedback through more in-class reviews on assignments

2. **We recommend that the Panamanian Government (AIG, SENACYT, or MEDUCA) run a similar ASSISTments trial in public schools, taking into account both the problems that our trial encountered and the following special considerations for public schools:**
    a. <u>Facilities may be limited:</u> Public schools and public school students are far less likely to have sufficient access to computers and internet than the private school that we worked with.
    b. <u>Teachers may require more training:</u> The teachers that we worked with were well educated, experienced with technology, and extremely enthusiastic about educational technology. As a result, teaching them how to use ASSISTments and how to incorporate it into their curriculum ran smoothly and quickly. It is possible that teachers in public schools may not have the same level of background knowledge and enthusiasm towards

ASSISTments, so more thorough training may be necessary before they incorporate it into their classrooms.

c. The language barrier will be more of a factor: Though content can be written in Spanish, all of the pre-built content in ASSISTments is in English, along with the interface. Being a bilingual school, this was no problem for the Panamerican school, but it would likely be an obstacle for many public schools.

3. **Develop similar trials with educational technologies other than ASSISTments.**

ASSISTments is not perfect, and other technologies may be more beneficial. It could be of great benefit to test different educational technologies that have different purposes to see their impact on Panamanian education. A few examples are:

a. Interactive educational game
b. Website where notes and videos can be posted
c. Messenger for student and teacher communication

4. **We recommend that the Panamanian government (AIG, SENACYT, or MEDUCA) institutes a program to both train and support interested teachers with the necessary facilities who want to use technology in their classrooms.**

Educational technologies in Panama tend to fail because of insufficient training and frustrations. To combat this, the Panamanian government could run an educational technology program and invite teachers who have proper facilities. A trainer will work with teachers. After a teacher feels comfortable with the educational technology he or she can begin adapting the tool to his or her curriculum. After classroom implementation has begun, the trainer needs to give the teacher all the support required to address any problems.

Authorship

Abstract

Authored by: Jennifer Golden

Edited by: All

Executive Summary

Authored by: Alex Gikas

Edited by: All

Introduction

Authored by: Alex Gikas, Casey Kracinovich

Edited by: All

Background

Authored by: Jennifer Golden, Casey Kracinovich

Edited by: Alex Gikas, Jennifer Golden, Casey Kracinovich

Research Questions and Methodology

Authored by: Alex Gikas, Jose Spiegel

Edited by: Jennifer Golden, Casey Kracinovich

Findings and Analysis

Authored by: Jennifer Golden, Jose Spiegel

Edited by: All

Recommendations and Conclusions

Authored by: All

Edited by: All

Other Major Contributions

Primary interviewer and translator: Jose Spiegel

Acronyms

AIG –Autoridad Nacional Para la Innovación Gubernamental (our sponsor)

MEDUCA – Ministry of Education of Panama
SENACYT – Secretaría Nacional de Ciencia, Tecnología e Innovación

OLPC – One Laptop Per Child

PISA – Programme for International Student Assessment
OECD – Organisation for Economic Co-operation and Development

TERCE – Third Regional Comparative and Explanatory Exam
SERCE – Second Regional Comparative and Explanatory Exam
LLECE – The Latin American Laboratory for Assessment of the Quality of Education

IMO - International Math Olympiad

Table of Contents

Table of Figures

Introduction

"Education," Nelson Mandela once said, "is the most powerful weapon [to] use to change the world." This is not an empty claim: the United Nations argues that if all of the world's students in developing countries had basic reading skills upon leaving school, world poverty would drop 12% ("UNESCO Millennium Development Goals: Education Counts," n.d.). Education is an important tool for curbing poverty, but those already in poverty often struggle with academic achievement, in a self-perpetuating cycle that generates educational and economic inequality in developing countries (Tomul & Çelik, 2009). Few places present a more powerful example of this effect than Latin America: 85% of Latin American students in the top fifth for income complete secondary school, but only 25% in the bottom fifth (*Challenges for Education With Equity in Latin America and the Caribbean*, 2011).

Panama is a typical example of poor Latin American education. Panama struggles immensely in math. A 2010 survey found that 95% of Panamanian teachers consider math to be the subject that their students struggle with most (Valderrama Bahamóndez & Schmidt, 2010). Panama's math education performs poorly by global standards. Of 70 countries/economies participating in the 2009 Programme for International Student Assessment (PISA) standardized exam, Panama ranked 69th in math. Similarly, Panama ranked 14th out of 16 Latin American countries/economies on the math portion of the Third Regional Comparative and Explanatory Exam (TERCE). Studies show that Panamanian math students struggle with basic skills such as the multiplication table and the four basic arithmetic operations (Valderrama Bahamóndez & Schmidt, 2010).

Educational technology is a recent global trend. Educational technologies include computers, Smartboards, and various software, such as websites. Large scale meta-studies demonstrate that under the right conditions, educational technologies can have a positive impact on student performance (Means et al., 2009, Cheung & Slavin, 2013). However, attempts to introduce educational technologies to the developing world have demonstrated that success in the developed world does not necessarily translate to success in a developing country such as Panama (Jere-Folotiya et al., 2014, Banerjee 2007).

One cautionary tale about implementing educational technologies in the developing world is the One Laptop Per Child (OLPC) program. One Laptop Per Child was founded in 2005 with the mission of providing laptops to children in developing countries to improve their education through access to technology. Despite its noble cause and intermittent success stories, OLPC has met harsh criticism for oversimplifying the complexities of education in developing countries and assuming that introducing laptops will cause "revolutionary change." In Peru, one of the most widespread adopters of the OLPC program, teachers were unprepared to incorporate the laptops into their teaching despite receiving training, as many of them had never used a computer before (Sonika Coomar & Ilia Ryzhov, n.d., Kraemer, Dedrick, & Sharma, 2009).

As the story of OLPC demonstrates, many obstacles arise when implementing educational technologies in developing countries. Many technologies are not accessible for students and teachers in developing countries who lack experience with technology. Educational technologies are useless and even counterproductive if teachers are not taught to use them properly. Technologies also often require expensive equipment and proper facilities. In order to be successful in Panama, educational technologies must be affordable, accessible, and practical.

One educational technology that could be used in Panama is ASSISTments, a website that specializes in math education. Unlike many other educational technologies, ASSISTments is free and accessible on any device with internet access. Its most noteworthy element is that it provides instant feedback to students and teachers. It aims to improve students' understanding and teachers' explanations in and out of the classroom.

The goal of this project was to work alongside the Autoridad Nacional para la Innovacion Gubernamental (see Appendix Z for more information) to determine if incorporating educational technology for math, such as ASSISTments, into Panamanian schools would improve test scores, student engagement, and teaching efficiency. Our major objectives were to:

1. Assess the state of middle school math education in Panama.
2. Assess Panamanian experiences and attitudes concerning educational technology.
3. Develop a feasible, efficient, and scientific trial to test ASSISTments in a Panamanian middle school.
4. Analyze the results of the ASSISTments trial through both test scores and student/teacher opinion.

We hope that ASSISTments will prove to be a helpful tool in Panamanian math classrooms, and that it will become a widely used educational technology that improves overall math test scores and education in Panama.

Chapter 2: Background

In this chapter, we will assess the potential and possible problems for educational technologies like ASSISTments to improve math education in developing countries such as Panama. We examine three subjects:

1. The Problems and Potential of the Panamanian Education System
2. Successes and Limitations of Educational Technology and its Potential in the Developing World
3. ASSISTments: Its Features and Uses

The goal of this chapter is for the reader to recognize the problems of Panamanian education, and see the potential successes and obstacles for an educational technology such as ASSISTments in Panama.

2.1 The Problems and Potential of the Panamanian Education System

The Panamanian education system lags behind surrounding countries of similar income levels. This is evident through Panama's performance on international standardized tests. This section intends to explain two topics:

1. Panama's education system and poor test performance.
2. Three problems that contribute to poor performance in education:
    a. An enormous socio-economic gap
    b. Limited government resources and funding
    c. Major government turnover every 5 years

Education in Panama consists of six years of compulsory primary school, followed by either an academic route consisting of two three-year cycles (roughly equivalent to middle school and high school) or a vocational route (Harris, n.d.). Enrollment is estimated at 95% for primary school and 60% for secondary school (Montoto, 2013). After completing high school, students earn their *bachillerato*, a degree generally required to enter higher education (Harris, n.d.). In 2011, enrollment in higher education was 41.8% (The World Bank, 2011).

Panama has scored poorly on international tests such as the 2009 PISA distributed by the Organization for Economic Cooperation and Development (OECD). The PISA exam "evaluates the quality, equity and efficiency" of about 70 countries/economies globally (OECD 2010). PISA is divided into three subjects: math, reading, and science. Panama's education is weakest in math. Globally, Panama was ranked 69th out of 70, and only outperformed Kyrgyzstan. Of all the Latin American countries (Colombia, Mexico, Argentina, Peru, Brazil and Panama), Panama performed the worst. The 2009 PISA math scores are displayed on a graph in **Figure 1.**

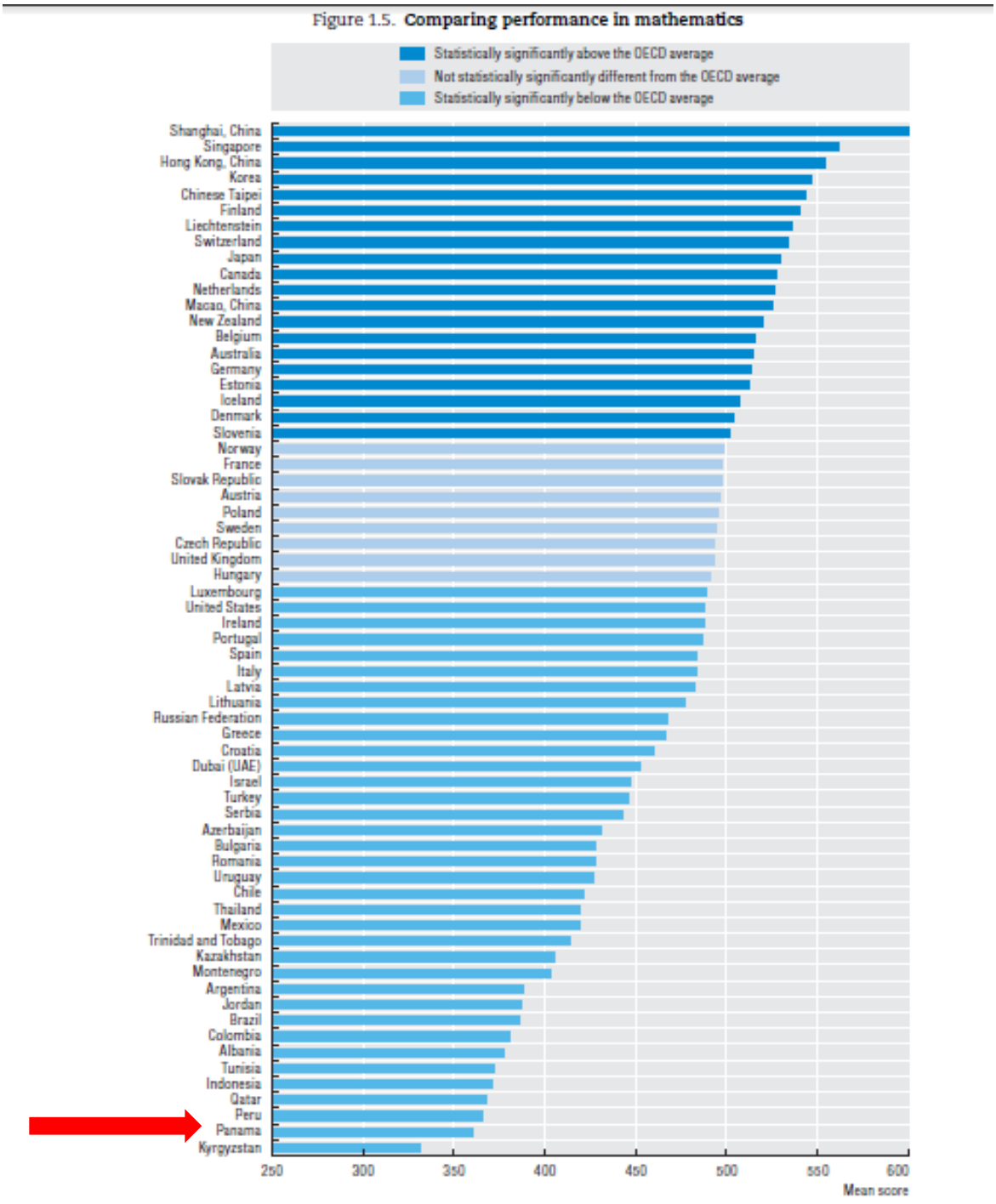


Figure 1 *PISA 2009 Math results (OECD, 2009)*

According to Jahir Calvo, coordinator of the PISA 2018 exam in Panama's Ministry of Education, due to similar economic standing, Panama's results should be more on par with that of Colombia (rank 57, score 413) (Calvo, personal communication). Instead, Panama's education is comparable to that of Peru (score 370) and Azerbaijan (362) (OECD 2010), which are much more economically

disadvantaged. Panama's science performance was similar to that of math and reading. The chart of overall results for PISA 2009 can be viewed in **Figure 2.**

COMPARING COUNTRIES' AND ECONOMIES' PERFORMANCE

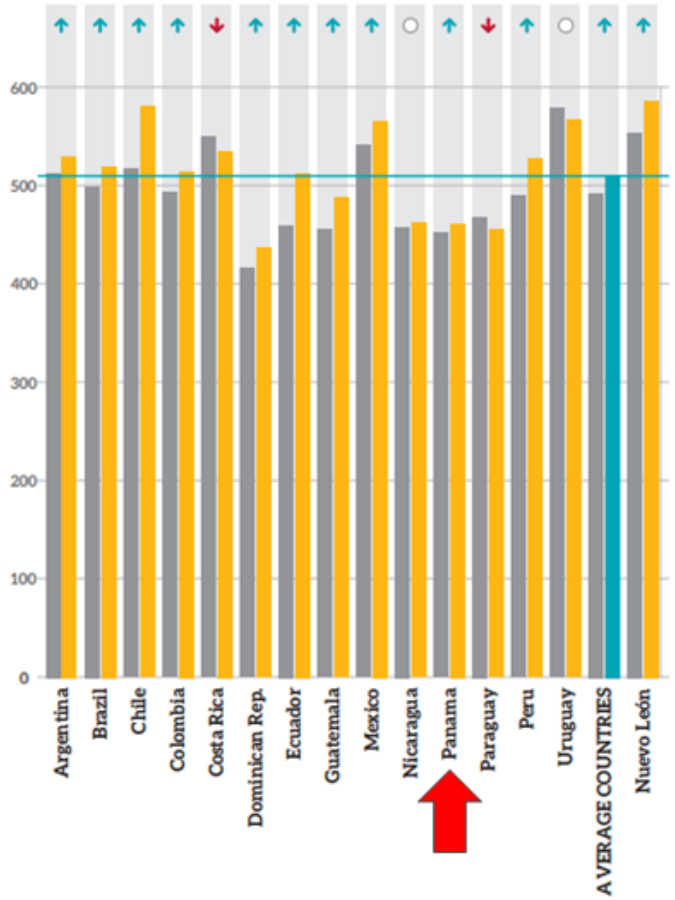
Statistically significantly above the OECD average
Not statistically significantly different from the OECD average
Statistically significantly below the OECD average

		On the reading subscales						
	On the overall reading scale	Access and retrieve	Integrate and interpret	Reflect and evaluate	Continuous texts	Non-continuous texts	On the mathematics scale	On the science scale
OECD average	493	495	493	494	494	493	496	501
Shanghai-China	556	549	558	557	564	539	600	575
Korea	539	542	541	542	538	542	546	538
Finland	536	532	538	536	535	535	541	554
Hong Kong-China	533	530	530	540	538	522	555	549
Singapore	526	526	525	529	522	539	562	542
Canada	524	517	522	535	524	527	527	529
New Zealand	521	521	517	531	518	532	519	532
Japan	520	530	520	521	520	518	529	539
Australia	515	513	513	523	513	524	514	527
Netherlands	508	519	504	510	506	514	526	522
Belgium	506	513	504	505	504	511	515	507
Norway	503	512	502	505	505	498	498	500
Estonia	501	503	500	503	497	512	512	528
Switzerland	501	505	502	497	498	505	534	517
Poland	500	500	503	498	502	496	495	508
Iceland	500	507	503	496	501	499	507	496
United States	500	492	495	512	500	503	487	502
Liechtenstein	499	508	498	498	495	506	536	520
Sweden	497	505	494	502	499	498	494	495
Germany	497	501	501	491	496	497	513	520
Ireland	496	498	494	502	497	496	487	508
France	496	492	497	495	492	498	497	498
Chinese Taipei	495	496	499	493	496	500	543	520
Denmark	495	502	492	493	496	493	503	499
United Kingdom	494	491	491	503	492	506	492	514
Hungary	494	501	496	489	497	487	490	503
Portugal	489	488	487	496	492	488	487	493
Macao-China	487	493	488	481	488	481	525	511
Italy	486	482	490	482	489	476	483	489
Latvia	484	476	484	492	484	487	482	494
Slovenia	483	489	489	470	484	476	501	512
Greece	483	468	484	489	487	472	466	470
Spain	481	480	481	483	484	473	483	488
Czech Republic	478	479	488	462	479	474	493	500
Slovak Republic	477	491	481	466	479	471	497	490
Croatia	476	492	472	471	478	472	460	486
Israel	474	463	473	483	477	467	447	455
Luxembourg	472	471	475	471	471	472	489	484
Austria	470	477	471	463	470	472	496	494
Lithuania	468	476	469	463	470	462	477	491
Turkey	464	467	459	473	466	461	445	454
Dubai (UAE)	459	458	457	466	461	460	453	466
Russian Federation	459	469	467	441	461	452	468	478
Chile	449	444	452	452	453	444	421	447
Serbia	442	449	445	430	444	438	442	443
Bulgaria	429	430	436	417	433	421	428	439
Uruguay	426	424	423	436	429	421	427	427
Mexico	425	433	418	432	426	424	419	416
Romania	424	423	425	426	423	424	427	428
Thailand	421	431	416	420	423	423	419	425
Trinidad and Tobago	416	413	419	413	418	417	414	410
Colombia	413	404	411	422	415	409	381	402
Brazil	412	407	406	424	414	408	386	405
Montenegro	408	408	420	383	411	398	403	401
Jordan	405	394	410	407	417	387	387	415
Tunisia	404	393	393	427	408	393	371	401
Indonesia	402	399	397	409	405	399	371	383
Argentina	398	394	398	402	400	391	388	401
Kazakhstan	390	397	397	373	399	371	405	400
Albania	385	380	393	376	392	366	377	391
Qatar	372	354	379	376	375	361	368	379
Panama	371	363	372	377	373	359	360	376
Peru	370	364	371	368	374	356	365	369
Azerbaijan	362	361	373	335	362	351	431	373
Kyrgyzstan	314	299	327	300	319	293	331	330

Source: OECD, *PISA 2009 Database*.
StatLink http://dx.doi.org/10.1787/888932343342

Figure 2 *PISA 2009 Overall Results (OECD 2009)*

The poor quality of Panamanian education can be put in a regional perspective by TERCE (Third Regional Comparative and Explanatory Exam) and SERCE (Second Regional Comparative and Explanatory Exam), international tests specific to Latin America taken in 2013 and 2006. The recent TERCE exam covered math, reading, and natural sciences for sixth- graders in eight Latin American countries. Panama did particularly poorly on the TERCE sixth-grade math category, scoring a 461 (3rd lowest). To contextualize, the lowest was the Dominican Republic with a score of 436 and the highest were the Mexican state of Nuevo Leon and Chile with 586 and 580. The countries with similar scores were Nicaragua (462) and Paraguay (455). Panama scored lower than Guatemala (487). Despite being in a similar financial situation to neighboring country Colombia, Colombia outperformed Panama, scoring 514 points, above the TERCE average. (LLECE 2014). The results of the sixth-grade math TERCE exam can be viewed in **Figure 3.**



	SERCE	TERCE	Difference SERCE-TERCE
Argentina	513.03	530.23	17.20*
Brazil	499.42	519.63	20.21*
Chile	517.31	580.51	63.20*
Colombia	492.71	514.69	21.98*
Costa Rica	549.33	535.19	-14.14*
Dominican Rep.	415.64	436.85	21.21*
Ecuador	459.5	513.12	53.62*
Guatemala	455.81	487.98	32.17*
Honduras		479.79	
Mexico	541.61	565.77	24.16*
Nicaragua	457.93	462.31	4.38
Panama	451.6	461.48	9.88*
Paraguay	468.31	455.55	-12.76*
Peru	489.98	527.25	37.27*
Uruguay	578.42	566.57	-11.85
AVERAGE COUNTRIES	492.19	511.22	19.04*
Nuevo León	553.95	586.68	32.73*

Figure 3 *TERCE exam results for sixth-grade math (LLECE 2014)*

According to Calvo, Panama did not perform as well as it should have on TERCE. Panama should have the resources to have an education system equal to that of Colombia because Panama is economically comparable to Colombia. Instead, Panama was on the same level as Nicaragua and Guatemala in math performance. (Calvo, personal communication).

In Latin America, Panama's spending per student is most similar to Colombia's, yet Panama's test scores lag far behind Colombia's. Panama spent 573 dollars per student in 2008 (4.1% Gross Domestic Product (GDP)), compared to Colombia's 645 dollars per student (5.1% GDP), Nicaragua's 62 dollars per student (3.2% GDP), and Guatemala's 241 dollars per student (3.2% GDP) (*Challenges for Education With Equity in Latin America and the Caribbean*, 2011). **Figure 4** shows dollars spent per student in each Latin American country and **Figure 5** shows the percent GDP spending for each Latin American country.

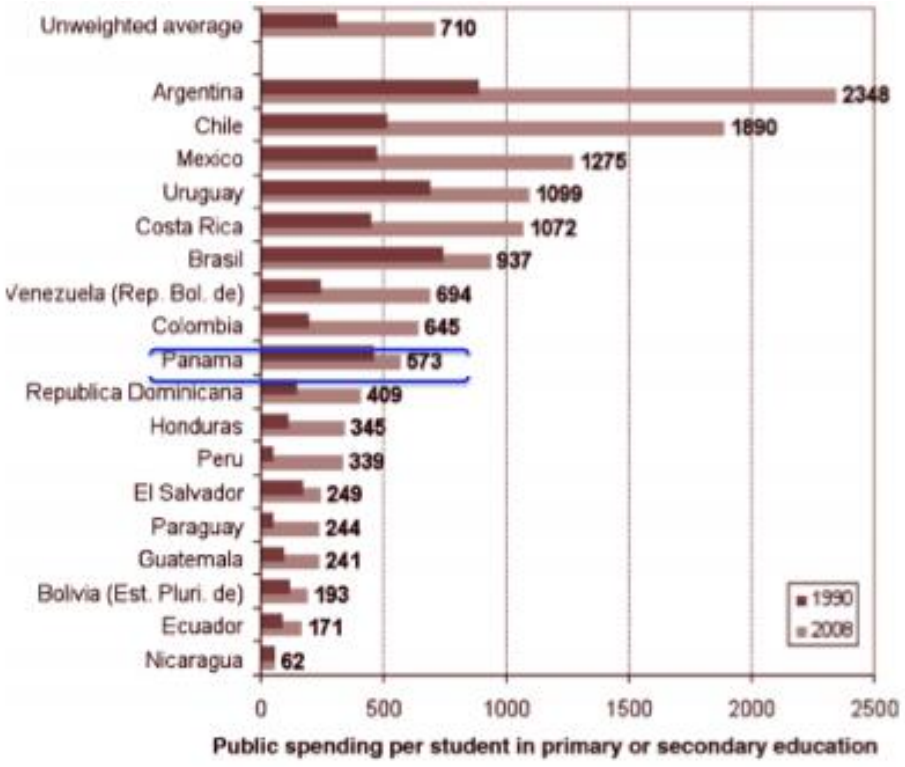


Figure 4 *Dollars Spent per Student (Challenges for Education With Equity in Latin America and the Caribbean, 2011)*

	Education spending as % of GDP		Education spending per capita		Population in age range for primary or secondary		Spending (primary & secondary) per person aged to receive it	
	1990	2008	1990	2008	1990	2008	1990	2008
Argentina	3.4	4.9	190	489	23.7	20.6	616	1773
Bolivia (Est. Pluri. de)	2.7	6.7	23	76	29.2	27.8	70	166
Brasil	4.6	5.3	154	232	24.6	19.3	349	911
Chile	2.7	3.6	83	224	22.3	19.8	258	837
Colombia	2.8	5.1	59	147	25.3	21.4	139	531
Costa Rica	4.5	5.2	140	268	23.8	20.2	331	974
Ecuador	2.6	2.1	34	36 [b/]	29.3	24.7	72	120
El Salvador	2.0	3.6	33	82	31.4	25.2	70	196
Guatemala	1.4	3.2	20	61	28.8	27.8	43	160
Honduras	3.7	7.0	39	101 [b/]	30.7	29.0	84	288
Mexico	4.0	5.8	197	378	27.8	21.6	398	1185
Nicaragua	4.4	3.2	30	29 [b/]	30.8	26.3	37	49
Panama	5.4	4.1	159	229	26.9	22.8	356	463
Paraguay	1.1	4.1	15	62	29.0	26.8	35	173
Peru	1.5	2.7	25	81	26.5	22.2	48	269
República Dominicana	2.0	2.5	37	91	28.7	25.1	80	279
Uruguay	3.1	3.1	169	272 [b/]	20.8	18.9	551	998
Venezuela (Rep. Bol. de)	3.1	3.8	150	227	25.7	21.7	144	515
Unweighted average	**3.1**	**4.2**	**86.5**	**171.4**	**27.0**	**23.4**	**205**	**549**

Source: Economic Commission for Latin America and the Caribbean (ECLAC), based on data from UNESCO Institute for Statistics (UIS) and ECLAC/Organization of Ibero-American States for Education, Science, and Culture (OEI), "Metas Educativas 2021: estudio de costos", Documentos de proyecto, Nº 327 (LC/W.327), Santiago de Chile [online at] http://www.eclac.org/publicaciones/xml/0/40520/metas-educativas-2021.pdf, 2010.

a The figures correspond to the administrative classification of public spending and may not coincide with figures derived from functional classifications.

b Population in the age range to study in primary or secondary education, according to the 1997 International Standard Classification of Education (ISCED).

c Estimates on the database of the UNESCO Institute for Statistics (UIS).

Figure 5 *Percent Spending per GDP on Education for Latin American Countries (Challenges for Education With Equity in Latin America and the Caribbean, 2011)*

Even Panama's best math students measure poorly against the best math students from around the world. Panama placed 99th out of 104 countries in the 2015 International Mathematical Olympiad (IMO), an invitation-only competition for top high school math students. Panama has sent students to the IMO for the past seven consecutive years and has had a dismal performance every year. In July 2015, the most recent competition, Panama's top students only performed better than Uganda, Ghana, Tanzania, Botswana and Bolivia. Countries with a similar socioeconomic level, such as Costa Rica (67th), Colombia (49th), and Paraguay (67th) ranked significantly higher than Panama (IMO 2015).

Three main reasons explain Panama's poor educational performance: the socio-economic gap, limited resources and funding, and the frequent government turnover. What follows is an explanation of each of these reasons.

1. **Socio-economic Gap:** Historically, education in Panama had pronounced disparities between social classes. After Panama gained independence from Colombia in 1903, the education system became segregated by social class. This segregation began to decrease in the 1920s because of United States influence (Harris, n.d.). Under a more inclusive education system, illiteracy dropped from more than 70% in 1923 to 28% by the 1950s. Rates have gradually continued to drop since then, to only 6% illiteracy today (Federal Research Division, 1987) (The World Bank).

Social disparities continue in Panama's education system. Students from the capital (Panama City) outperformed students in rural Panama by over 100 points in reading on the 2009 PISA exam (OECD, 2011). As seen on the graph in **Figure 6**, Panama has the largest global deviance between rural areas and large cities in 2009 PISA test scores. While the average for large cities is still far below the global OECD exam average, it is still significantly higher than the average score for students in rural areas.

Major education gaps exist between the indigenous population and the non-indigenous population. In 2002, 94% of non-indigenous students finished primary school, as compared to 55% of the indigenous population (Harris, n.d.). In 2008, 88% of the indigenous and African ethnic population in Panama don't graduate high school (*Challenges for Education With Equity in Latin America and the Caribbean*, 2011).

A large gap also exists between the public and private education sectors. Panamanians able to attend private school receive a much better education than those attending public school. Private schools provide a higher quality of education because they have more funding, more resources, and longer hours. Many public school teachers are also part-time private school teachers, but often focus their efforts on their teachings at private school. A teacher's job security at private high schools depends on student's continued enrollment. At public high schools, teachers' jobs are secure because the strength of teacher unions makes it extremely difficult to fire public sector teachers (Calvo, personal communication).

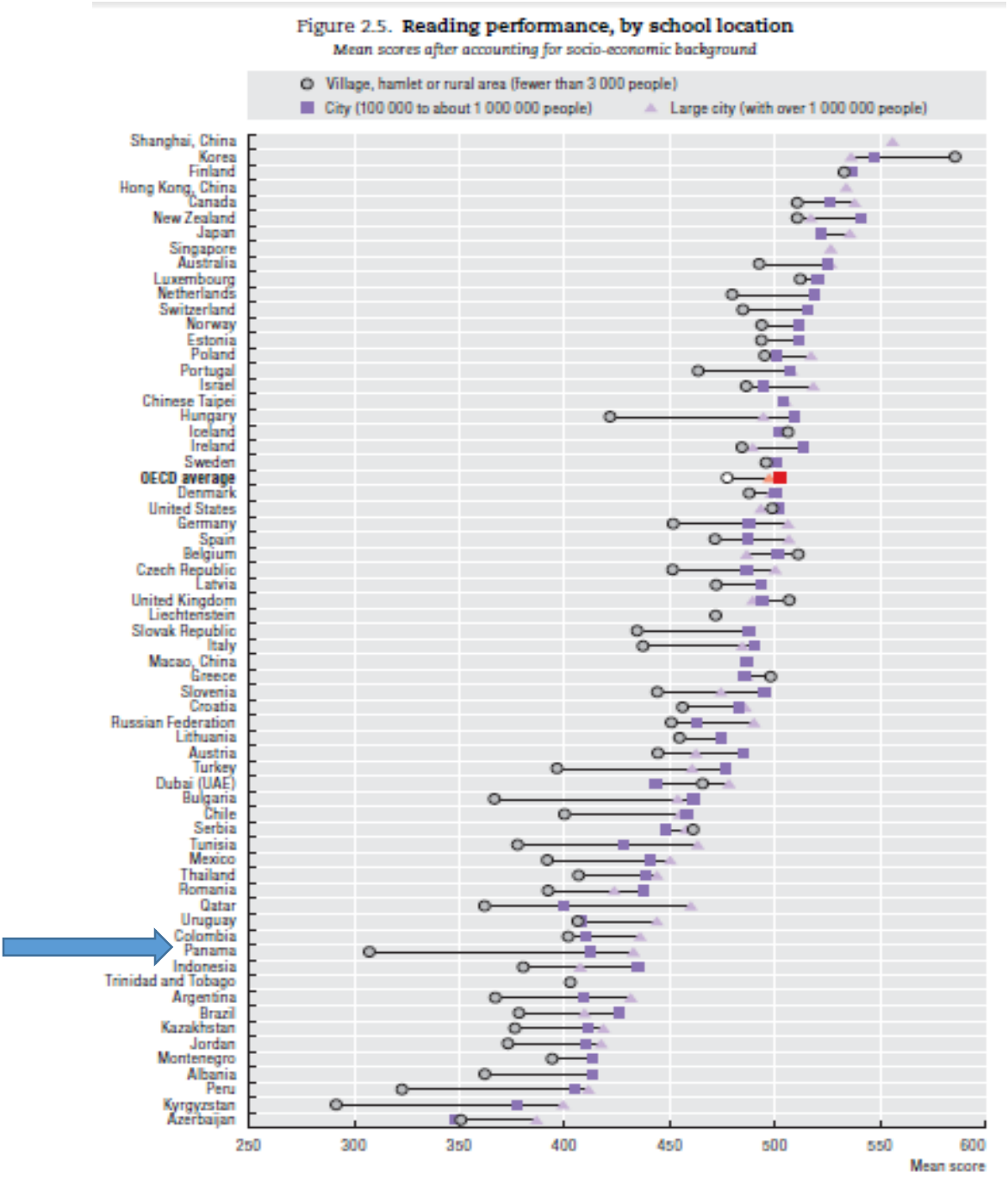


Figure 6 *Deviance in PISA Reading Scores between Rural Areas and Cities (OECD 2009)*

2**. Limited Resources and Funding**: Insufficient funding and resources significantly impact Panamanian education. Spending on education has dropped from 4.3% of the GDP in 1980 to 3.8% in 2008 to 3.5% in 2011 (The World Bank, n.d.). Decreases in funding greatly diminish the quality of education by

limiting space, personnel, and technology, particularly in public schools. The country does not lack money, but directs its investment in education poorly.

Because there are not enough school buildings or teachers to accommodate the large number of students, most public schools in Panama only hold classes for half the day. Students do not have enough class time for effective learning. Most schools run classes in two sessions, one from 7 to 11 am and another from 12 to 4 pm. The building is then used for higher education at night (Calvo, personal communication).

The economically disadvantaged have highly limited access to technology such as computers and the possible educational advantages that it may provide. Overall, 77% of Panamanian students have some access to a computer in school, but only 44% have internet access. These percentages drop in homes, where only 44% of students can access a computer and only 36% have internet access (*Challenges for Education With Equity in Latin America and the Caribbean*, 2011). However, cell phone use is widespread.

3. Inconsistency of Government: The Ministry of Education has a near complete government turnover every five years, making governmental education reform extremely difficult. When a new Minister of Education is elected for a non-renewable five year term, he or she selects who will fill all of the ministry coordinator positions. Reforms started during a new term are rarely continued until their completion. In general, many educational improvement programs are not fully implemented, meaning they do not last the time required to see an impact on education (Calvo, personal communication). According to the Ministry of Education math department head, Gibzka de Vernier, the government has attempted to implement programs to better train teachers and to expand the curriculum. These efforts are neither successful, nor unsuccessful, as they are never concluded before a new government term begins (de Vernier, personal communication).

2.2 Successes and Limitations of Educational Technology in the Developing World

Educational technology is a widely used and constantly growing educational resource, showing strong promise for the future. Use of educational technologies has skyrocketed with the internet age (Means, Toyama, Murphy, Bakia, & Jones, 2009) (Cheung & Slavin, 2013). However, many factors limit the potential for educational technology to spread to the developing world.

Overview of Educational Technology: Studies have shown that on average educational technologies improve student performance, particularly when they are used in conjunction with traditional in-person teaching. An exhaustive 2009 meta-study of online learning found that educational technologies improved student performance, especially in a "blended" approach where students also learn in a traditional classroom setting. It should be noted that this meta-study found only five acceptable studies covering K-12 learning, and most of the 46 studies were for higher education (Means, Toyama, Murphy, Bakia, & Jones, 2009). A more specific meta-study published in 2013 covered K-12 math educational technology, and found that educational technology generally had a "modest" positive impact on learning. The most success was found in supplemental Computer-Assisted Instruction (CAI), where educational technologies provide a supplement to traditional teaching (Cheung & Slavin, 2013).

Educational technology takes many forms. One example is **Wayang Outpost**, which was developed at UMass Amherst as a study tool for the math section of the American Scholastic Aptitude Test (SAT). It features a brightly animated story and many game-like features as hooks and framing devices for its educational content. It is designed to adapt its curriculum to each student's skills, interest, and even emotions. A study conducted found that students showed significant improvement in their SAT math skills after only an hour of use (Arroyo, Wallace, Beal, & Woolf, 2003).

Another example of an educational technology is **GraphoGame**, a mobile educational game originally from Finland that helps first-grade students learn to read. It helps students make connections between letters and the sounds associated with them. This is done by making students choose a letter based off of a given sound (Richardson & Lyytinen, 2014).

Developing Countries & Limitations: Many obstacles hinder implementing educational technology in a developing country. One 2011 study, *Education Technology for the Developing World*, found that obstacles include economics, and a lack of computers, internet access, electricity, and physical infrastructure like classrooms and buildings (Woolf, Arroyo, & Zualkernan, 2011). According a 2012 survey of 76 Information and Communication Technologies (ICT) experts and faculty based in the developing world, the most influential factors in successful introduction of e-learning to developing countries are: perceived usefulness, attitude towards e-learning, and program flexibility (Bhuasiri, Xaymoungkhoun, Zo, Rho, & Ciganek, 2012). In the 2003-2004 academic year, an exploratory study was developed in Hims (Syria's largest city), to explore the attitudes of high school English as a Foreign

Language (EFL) teachers towards ICTs**.** It found that developing countries need to create a level of acceptance towards computers before actually using them. The teachers' attitudes towards ICTs were correlated with computer attributes, computer competence, and cultural perception (Albirini, 2006).

What follows are a few examples of educational technologies implemented in the developing world:

1. Researchers introduced the mobile reading tutoring game **GraphoGame** to schools in Zambia in attempt to help first-grade students learn to read their native Bantu language. Researchers identified particular problems with the way that reading was taught in Zambia, such as the hazy connection between letters and the sounds associated with them and the outside influence of the English language, and specifically calibrated their trial to address these problems. The study suffered frequent real-world setbacks due to the erratic nature of the Zambian school system, such as overcrowding, weak infrastructure, poor working conditions of teachers, low levels of family literacy, scarcity of teaching materials, and absenteeism of students. In spite of these setbacks, the researchers found that GraphoGame produced significant positive effects in student literacy. Students improved far more when teachers were familiar with GraphoGame and its teaching approach so that they could give proper instruction that supported GraphoGame, rather than accidentally working against it (Jere-Folotiya et al., 2014).
2. **One Laptop Per Child (OLPC)** was founded in 2005 with the mission of developing and providing children in developing countries with a "rugged, low-cost, low-power, connected laptop", so that children "are engaged in their own education, and learn, share, and create together". Despite its noble cause and intermittent success stories, OLPC has met harsh criticism for oversimplifying the complexities of education in developing countries and assuming that introducing laptops will cause "revolutionary change". In Peru, one of the most widespread adopters of the OLPC program, the effects of the program have been questionable at best. Despite receiving training, teachers were unprepared to incorporate the laptops into their teaching, as many teachers had never used a computer before. Though OLPC recommends that children be able to take their laptops home, many schools did not allow this for fear that the laptops would be sold. Some of these same schools did not have electricity, leaving no way for the children to charge their laptops. The Indian government outright rejected OLPC, prioritizing their teachers and infrastructure over expensive laptops (Sonika Coomar & Ilia Ryzhov, n.d.) (Kraemer, Dedrick, & Sharma, 2009).
3. In a two year study designed to investigate new ways to improve education in India, fourth-graders attending public schools in Vadodara, India participated in a **Computer-Assisted Learning Program (CAL)**. An early problem encountered by the study was that some schools were physically unable to install computers because they did not have electricity. The students worked in pairs on the computers for two hours per week, playing educational math games

which would adjust the difficulty to challenge students based off their performance. The program resulted in improvement in math test scores by a standard deviation of 0.35 in the first year and 0.47 in the second year. This study, in addition to the CAL program, also included a second trial program using local young women as teachers. Although the CAL program resulted in higher overall math scores, using tutors was ultimately 5 times more cost effective (Banerjee 2007).

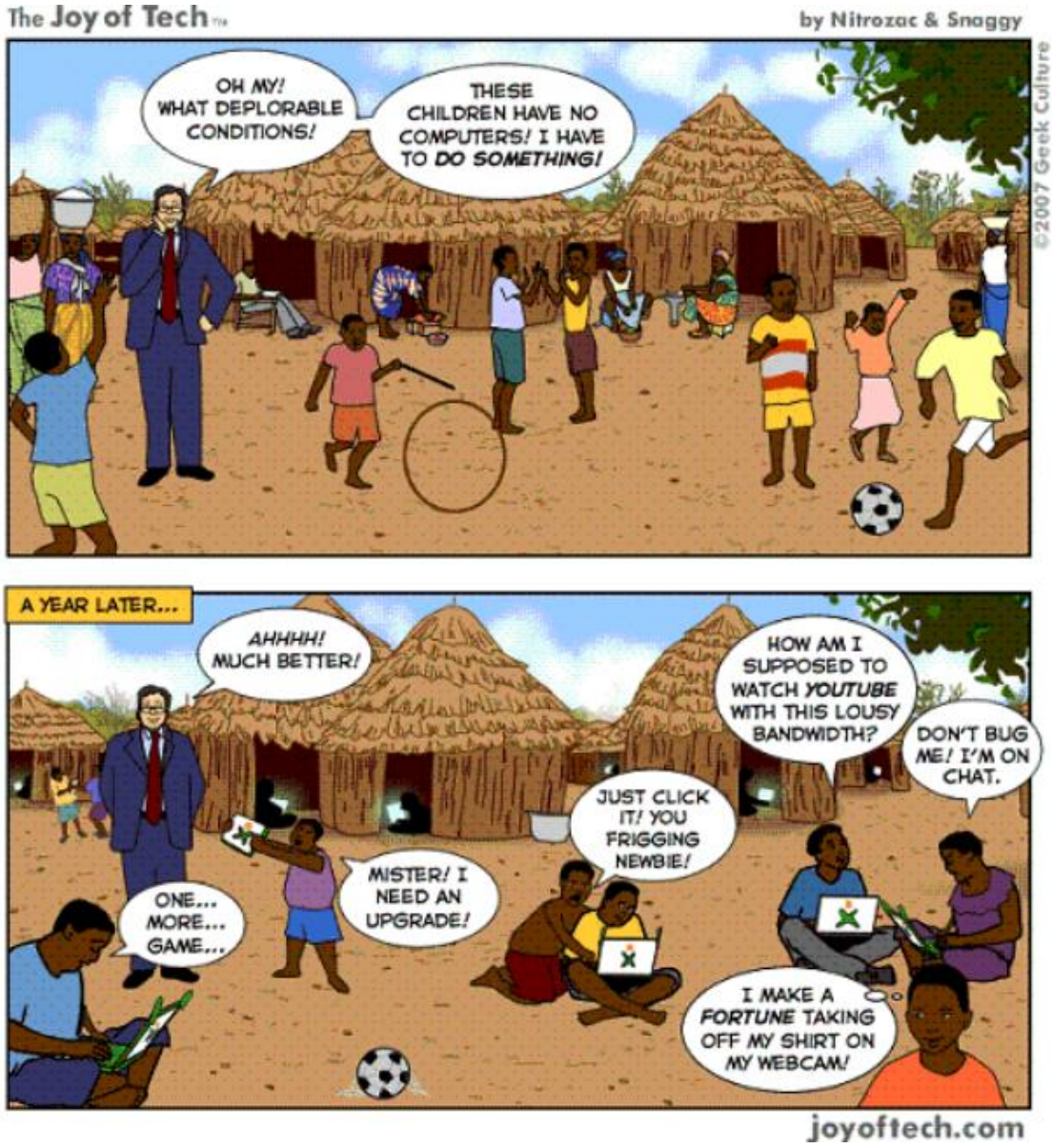


Figure 7 *A cartoon satirizing One Laptop Per Child (Sonika Coomar & Ilia Ryzhov, n.d.).*

Lessons Learned: Based on studies done by others who want to implement educational technologies, we should be able to answer following questions before implementing an educational technology in a developing country:

1. **Is it economically feasible?** As predicted by Woolf, and demonstrated in the cases of One Laptop Per Child and the Computer-Assisted Learning Program, money is always a concern when dealing with technology. Not only must the educational technology be affordable in first place, but the positive results must be worth the monetary effort.
2. **Does the country have access to the proper facilities?** Lack of electricity was a problem that plagued both OLPC and the CAL. Additional considerations include internet access, access to computers, and physical workspaces, like classrooms.
3. **Do we understand the problem we are trying to solve?** OLPC's most fundamental flaw was that it failed to question the reasoning behind its own existence. Its actions assumed that the lack of computers in itself was a problem, rather than considering the complexities of technology and education in the developing world. To combat this lack of direction, we must have a clear agenda as to the problems that we aim to solve.
4. **Is the technology actually wanted or necessary?** The survey of ICT experts and faculty in the developing world and the Syrian study both made it clear that attitude towards technology and the perceived usefulness are important. Teachers and students who do not see the value of the technology will not bother making the effort of learning to use it properly.
5. **Do teachers fully understand the technology and its goals?** Both GraphoGame and OLPC demonstrate the importance of teacher understanding; if teachers are misinformed or confused, they may inadvertently work against the educational technology. Communication with teachers is absolutely essential because they will be overseeing the day-to-day implementation more closely than anyone else.
6. **How adaptable and flexible is the technology?** Numerous setbacks are inevitable when incorporating technology in a developing country. The ICT survey proposes an answer: program flexibility. Teacher and students who use educational technology must be able to adjust the technology to fit their specific needs. Educational technologies implemented in developing countries must be flexible and allow some degree of improvisation in order to be successful.

2.3 ASSISTments: Its Features and Uses

ASSISTments is a free website created in 2003 by Neil and Cristina Heffernan along with several other professors at Worcester Polytechnic Institute (WPI) located in Worcester, Massachusetts, USA, in conjunction with Carnegie Melon University, located in Pittsburgh, Pennsylvania, USA. Combining an online tutor with online assignments, ASSISTments helps students through problems, and provides immediate assessment of their understanding of the subject matter. The development of ASSISTments began with the goal of creating a digital teaching platform geared towards middle school math preparation for standardized tests. It has now expanded to include other subjects such as statistics, science, and chemistry.

Overview of the Unique Features of ASSISTments: According to the designer, many features of ASSISTments are "designed to enhance what the teacher is already doing, but they also allow them to do it in a more efficient manner" (Heffernan 2012). What follows is a list of the features of ASSISTments:

1. Scaffolding questions**:** Scaffolding questions break questions into simpler steps so that students can learn the process of a solving a problem one step at a time. They are designed to mimic the process of a human tutor.
2. Hints: Many questions give students the option to view simple hints designed to guide them in the right direction. An example of a sequence of hints a struggling student would see is shown in **Figure 8.**
3. Buggy messages: Buggy messages appear when students give a specific incorrect answer. Teachers can include an explanation of what went wrong and how the student can solve the problem on their next try.
4. Variable questions: In order to create a larger library of questions for ASSISTments, many questions were written as formulas with variables in them which randomly generated numbers. Researchers found that students learned more effectively when assigned questions in pairs, one being the original problem a 'morph' created using the variable method (Razzaq *et al.* 2005).
5. Skill Builders: Skill Builders are a specialized type of assignment that make students master a "skill" by having students answer a set number of a particular type of problems correctly in a row.
6. The Builder: ASSISTments offers teachers the ability to build their own content on a tab called the builder. As the program grows and more people write content, material is added to ASSISTments database. Content can be reused by other teachers, as long as it is approved by

the ASSISTments creators. This can save teachers a lot of time and effort when creating their assignments. **Figure 9** is a screenshot of the builder.

One Massachusetts teacher finds that problems she builds herself are more 'accessible' to students through the use of added photos and video clips (Cox, n.d.). Despite this, creating content is not simple. We found that the builder section of ASSISTments is not user-friendly and requires a lot of practice to get used to. Cox finds that it is time consuming to create new assignments. The end quality of these assignments depends on the amount of time and effort the teacher is willing to invest (Cox, n.d.).

7. Teacher reports: After giving an assignment, the teacher can see statistics per question such as percent correct overall, every answer a student gave, hints used, and common wrong answers, as seen in **Figure 10**. With this detailed information, the teacher knows what topics to focus the next lesson on. The teacher can also "anonymize" the report to remove student names. This allows teachers to be able to project the report so that students can see the overall class performance.

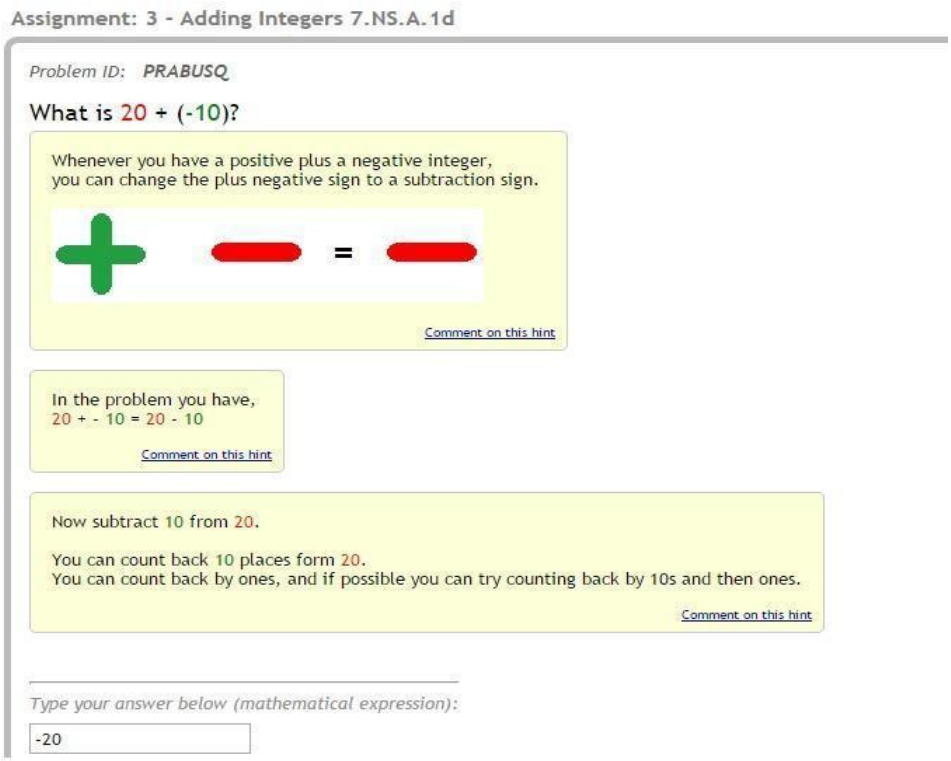


Figure 8 *A screenshot of an ASSISTments problem with hints (screenshot from ASSISTments website).*

Student/Problem [Unanonymize]	Average Data driven	PRAQW3F Data driven	PRAQW3G Data driven	PRAQW3H Data driven	PRAQW28 Data driven	PRAQW29 Data driven	Total Hints	Time Spent
Problem Average Graph	51%	43%	43%	43%	71%	57%		
Common Wrong Answers								
Correct Answer(s)		*The sides will decrease by 1/2*	*1*	*4*	*16*	*The area of WXYZ is 25 times the area of ABCD.*		
XXXXXXXX	40%	✗ It cannot be determined.	✗ what?	✗ 2	✓ 16	✓ The area of WXYZ is 25 times the area of ABCD.	0	00:02:48
XXXXXXXX	60%	✗ The sides will stay the same.	✓ 1	✓ 4	✓ 16	✗ The area of WXYZ is 20 times the area of ABCD.	0	00:01:36
XXXXXXXX	40%	✗ The sides will stay the same.	✓ 1	✗ 6	✗ 6	✓ The area of WXYZ is 25 times the area of ABCD.	1	00:01:07
XXXXXXXX	60%	✓ The sides will decrease by 1/2	✓ 1	✗ 0	✓ 16	✗ The area of WXYZ is 5 times the area of ABCD.	0	00:01:25
XXXXXXXX	80%	✓ The sides will decrease by 1/2	✗ 0	✓ 4	✓ 16	✓ The area of WXYZ is 25 times the area of ABCD.	1	00:01:33
XXXXXXXX	0%						0	N/A
XXXXXXXX	0%						0	N/A
XXXXXXXX	80%	✓ The sides will decrease by 1/2	✗ 0	✓ 4	✓ 16	✓ The area of WXYZ is 25 times the area of ABCD.	0	00:02:21
XXXXXXXX	0%	✗ The sides will stay the same.	✗ 0	✗ 2	✗ 8	✗ Hint requested	4	00:03:46

Figure 9 *A teacher's view of the assignment report (screenshot from ASSISTments website).*

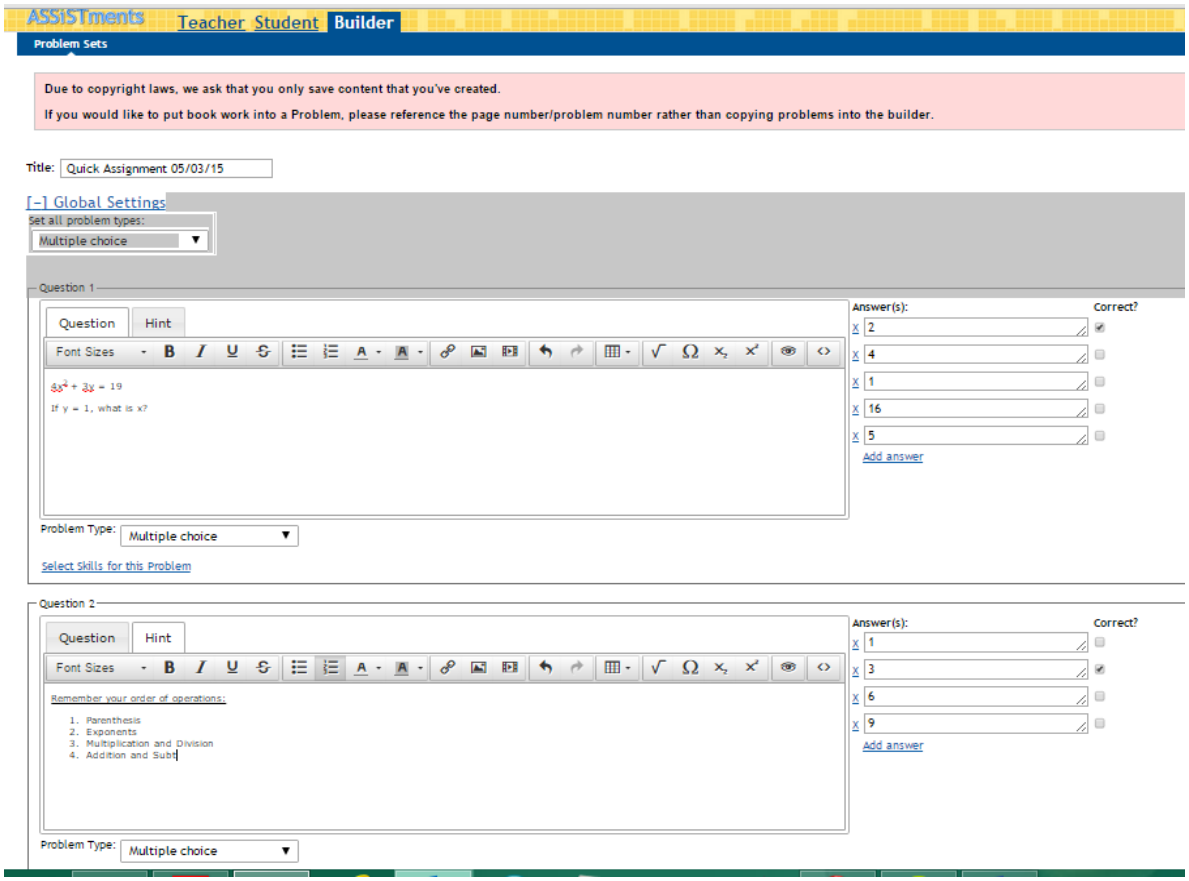


Figure 10 *A screenshot of the question builder on ASSISTments (screenshot from ASSISTments site).*

Possible Uses of ASSISTments: ASSISTments has been incorporated into US classrooms in various ways depending upon the needs of the specific class and teacher:

1. Homework: Some teachers use ASSISTments for nightly homework on specific skills. This is beneficial on two fronts. First, teachers receive a detailed student performance report without putting a large amount of time into grading. They can use this report to prepare the next day's lesson to be as effective as possible for students. Teachers can see which questions caused the most difficulty for students and can focus the review on these questions. If the class had a good overall understanding on a specific question or topic, they can move on without wasting class time. Second, students receive feedback on their work as they complete it, as opposed to waiting until the next morning, at earliest. Along with knowing immediately if an answer is right or wrong, students will receive hints and explanations for some wrong answers as they work.
2. Exam Practice: ASSISTments can also be used as exam practice. This could be practice for unit tests, semester tests, or standardized tests. Eric VanInwegen is a Massachusetts teacher who prepares his high school chemistry class for the AP exam with this learning tool (VanInwegen personal communication).
3. Classroom Practice: ASSISTments is useful when doing in-class assignments because teachers can see how students are doing on the assignment as they work on it. Common wrong answers can be reviewed on a projector immediately. This allows students to discuss and understand what went wrong while it is still fresh in their minds. An example of this implementation is Oxford Middle School (Oxford, MA). Oxford Middle School has students attend 'Math Lab' once a week where they spend the period in a classroom doing ASSISTments work as assigned by a supplemental math teacher (Oxford visit).
4. Warm-up Question: ASSISTments can also be used as a warm-up question. At the start of the class the students will complete a question or assignment. Typically, this is a review question from the previous day to refresh students.

Evaluation of ASSISTments: We have found very little quantifiable evidence evaluating ASSISTments' ability to improve learning. Our best source is a study published by the Heffernans, in which one New England urban school system used ASSISTments for state standardized test preparation and the student's average performances in each class were tracked every month. Over the course of two years, students using ASSISTments for seventh-grade math experienced a higher increase in spring state standardized test scores than the schools that did not use ASSISTments (Heffernan, Heffernan 2015).

Chapter 3: Research Questions and Methodology

The goal of our project was to work alongside the Autoridad Nacional para la Innovacion Gubernamental to determine if incorporating educational technology for math such as ASSISTments into Panamanian schools' math education could improve test scores, student enjoyment, and teaching efficiency. In order to accomplish this goal we pursued four objectives:

1. Assess the state of middle-school math education in Panama.
2. Assess Panamanian experiences and attitudes concerning educational technology.
3. Develop a feasible, efficient, and scientific trial to test ASSISTments in a Panamanian middle school.
4. Analyze the results of the ASSISTments trial through both test scores and student/teacher opinion.

In this chapter, we will elaborate on these objectives and explain the steps we took in order to complete them.

Objective 1: Assess the State of Middle-School Math Education In Panama

Knowledge Sought. We decided that the following questions would help us understand math education in Panama as it relates to our project:

1. Which components of Panamanian math education are most in need of improvement?
2. How is math education perceived by students?
3. How is math education perceived by teachers?

The answers to these questions helped us to develop a baseline and set feasible standards. Knowing the current drawbacks of math education helped us understand what we were trying to improve through introducing ASSISTments to Panamanian schools.

Method. We completed the majority of this research through interviews and concise surveys with teachers and students. We surveyed 100 local private school students and a wide-range of math teachers across Panama. We asked students and teachers opinion-based questions aiming to determine their opinions on the subject of math, and current math teaching methods. Student survey questions can be found in **Appendix C,** and teacher survey questions are in **Appendix D.**

More in-depth interviews were conducted with two local private school math teachers and government officials. These questions can be seen in **Appendix** E. We interviewed Jahir Calvo (MEDUCA planning coordinator), Manuel Navarro (MEDUCA regional math head) Gibzka de Vernier (MEDUCA math department head). These questions are in **Appendix F**. We asked them more open-ended questions on their opinions and experiences with Panamanian math education.

Justification of Method. Interviewing was a good way to obtain credible opinions on math education directly from students and teachers. We chose to interview the two math teachers in person to obtain candid, honest responses. Surveys were used to obtain a wide range of responses from students and teachers because interviewing them all would not be feasible within the time constraints of this project. We thought that teachers and students were more likely to complete surveys asking for concise responses rather than those requiring them to give long responses.

Analysis Method. The information received from the interviews and surveys with students and teachers was largely opinion-based. We tried to find recurring responses so that we could best categorize responses. We made graphs and charts detailing the common answers given on surveys.

Limitations. Our interviewees could have given us biased or otherwise unreliable information. To overcome this limitation, we strived to find the most qualified people to interview and substantiate as much information as possible with multiple sources.

Interviews were limited because of time restraint, and lack of contacts with reputable people with knowledge of Panamanian math performance.

Another obstacle was that we only had one school available to work with us (the Panamerican School). Since this school was a private school, the student survey results would be representative of only a portion of the population not including any representation from the public sector.

Objective 2: Assess Panamanian experiences and attitudes concerning educational technology.

Knowledge Sought. We strived to understand which educational technologies have been previously used in Panamanian education, and their influence. We also wished to understand student and teacher opinions on educational technologies.

This knowledge allowed us to understand the level of training necessary for use of ASSISTments. We also were able to understand any past frustrations students and teachers have had so that we can best avoid them.

Method. This research was completed through interviews with two local private school teachers, these questions are available in **Appendix E.** We interviewed Maria Heller (SENACYT Innovation Director of Science Learning), Manuel Navarro (MEDUCA regional math head), and Gibzka de Vernier (MEDUCA math department head). These questions are available in **Appendix F.** We surveyed 100 middle-school students at a local private school, and middle-school math teachers across the country. We asked opinion-based questions to determine opinions on the educational technologies. We also asked what

their previous experience was with educational technologies, if any. Student survey questions are available in **Appendix C,** and teacher survey questions are included in **Appendix D.**

Justification of Method. We wished to get our information directly from students and teachers. We chose to give out short surveys in the hopes that they would be completed quickly and easily. Many of our survey questions were multiple choice, or asked the responder to select a level on a scale. This was to avoid wording our questions in a way which would favor certain responses.

Analysis Method. The information that we received from surveys to students and teachers was largely opinion-based, on scales and through multiple choice. This made it easy for us to categorize responses and determine majority opinions. We also made graphs and charts of the results.

Limitations. We were constrained by time, so the fastest way to get responses outside of one specific local private school was through an internet-based survey. This greatly narrowed the responses we could get from teachers since internet access is limited throughout Panamanian schools.

The only students we could feasibly survey were those in the classes we were working with. This greatly narrowed our results because the public sector was not represented.

Objective 3: Develop a feasible, efficient, and scientific trial to test ASSISTments in a Panamanian middle school

Knowledge Sought. We wanted to determine the characteristics of a "good" trial to test ASSISTments in a Panamanian school. We had to determine what shape our trial could take in order to be completed within our short time frame of roughly two weeks of classes, while being tailored to the specific classes that we would be working with.

Methods. We researched educational research design in attempt to create a trial that would produce credible data, while still accounting for various real-world obstacles. We also spoke with one local private school, the Panamerican School, teachers in order to know what trial design would be feasible with the classes they had to offer us.

Justification of Method. Due to our short time frame, it was important that we based the design of our trial on what research has shown to be reliable. We did not have time to experiment with different trial configurations.

Limitations. It was difficult to develop a trial that could be completed in such a short span of time while still producing reliable results.

Objective 4: Analyze the results of the ASSISTments trial through both test scores and student/teacher opinion

Knowledge Sought. We wished to learn if ASSISTments was effective in three different ways:

1. If ASSISTments had an impact on the students' test scores.
2. Teachers' and students' opinions regarding the technology's effects on their learning and teaching.
3. If the teachers were more time efficient when using ASSISTments and if the students felt more engaged with their work.

Method. The two classes we worked with at a local private school, the Panamerican School, were a seventh-grade arithmetic class and an eighth-grade geometry class. According to our research, the best fit for our trial was a quasi-experimental design in which we had two different math classes split into experimental and control sections (Joy 2007). We gave both the experimental and control sections a pretest to gauge their prior knowledge at the start of a trial.

Before starting the trial, we taught both teachers how to use ASSISTments for their classrooms in three 2 hour training sessions. In the first session we introduced the teachers to ASSISTments. In the next two sessions, we helped the teachers tailor their curriculums to ASSISTments, planning assignments so that they could take advantage of its unique features without dramatically altering their usual teaching.

Over the course of two weeks, the experimental section used ASSISTments wherever possible while the control group continued with traditional teaching. The seventh-grade arithmetic class met every day. The experimental class section used one-question assignments in ASSISTments at the end of five classes. They then completed a day with an extensive ASSISTments assignment called a workshop. The teacher used ASSISTments data to review the workshop. The control section completed these assignments on paper.

The eight-grade geometry class met only twice a week. The plan was originally for the experimental section to use ASSISTments in two class sessions, with a short classwork and a homework for each session. The plan for the control section of this class was traditional classwork and no assigned homework. We were ultimately forced to stop working with the eighth-grade class because of unexpected scheduling changes and our time constraints

At the end of the two week trial, we handed out a posttest similar to the pretest in both seventh-grade class sections. We also gave students surveys to determine student opinions on ASSISTments after the trial. These survey questions are in **Appendix G.** We then interviewed the teacher

of the seventh-grade class in order to obtain more extensive opinions on the technology. The interview questions can be found in **Appendix H.**

Justification of Method. In order to validate the improvement of education through ASSISTments, we broke down our analysis of the ASSISTments trial into three major categories. Test scores were statistics that could be proven directly. Student and teacher opinions are crucial due to their influence over effective education. Through surveys, we determined if students felt engaged using ASSISTments.

Analysis Method. We compared the test results from the pretest with the posttest to see how each class section improved over the course of the trial. We then compared to see if the experimental section did better, worse, or similar to the control section. We categorized our survey answers by common opinions on ASSISTments and on math education while using ASSISTments. We compared opinions on math education before and after ASSISTments for both the experimental and control groups to see if students' opinions had shifted.

Limitations. One obstacle was credible survey responses. It was difficult to make sure that students were answering questions truthfully. To overcome this, we worded the questions carefully to prevent influencing student responses in any way. If any of our recovered data was misinterpreted, then our results could be off.

Our test only ran for two weeks in one class of twenty-four students, so it is difficult to generalize our findings to the Panamerican School as a whole, let alone all of Panama. Being unable to work with the eighth-grade class decreased our sample size further. It also resulted in having only one teacher's final opinions.

Using only the seventh-grade class, we saw less variety in how ASSISTments was used. We did not see ASSISTments used for homework during the trial at all. Using ASSISTments in class could have produced very different results than using the website for homework. Some of the features of ASSISTments, hints and teacher feedback, are more valuable when the website is used outside of class.

The Panamerican School's student internet connection was unreliable. Some days it would not work very well for all students. This may have limited the sample size of students using ASSISTments further.

Chapter 4: Findings and Analysis

Objective 1: Assess the state of middle-school math education in Panama

Finding 1: Because most teachers, particularly in primary school, have received inadequate training, they generally teach using "old-fashioned" methods focusing on rote memorization, thus undermining students' basic skills, retention levels, understanding of math applications and analysis, and test performance.

Summary of Evidence: Drawing from our teacher and student surveys, interviews with government officials and teachers, and pieces of additional research, we discovered that education follows a progression.

1. Teachers, particularly primary school teachers, receive inadequate preparation (de Vernier, personal communication, Navarro, personal communication).
2. Teachers generally teach with an "old-fashioned" teaching style, with an emphasis on rote memorization, rather than analysis (de Vernier, personal communication, Navarro, personal communication, Powell, personal communication, Serracin, personal communication).
3. Students have poor basic skills and retention (Navarro, personal communication, Serracin, personal communication).
4. Students do not learn critical analysis or practical applications in math (Powell, personal communication, de Vernier, personal communication)

Discussion/Explanation: Primary school teachers in Panama are only required to complete high school, with a specialized teaching diploma. Secondary school teachers are required to obtain a college degree in their specialization area. Many of the people that we interviewed described primary school teachers' education and preparation as inadequate.

Many of the people that we interviewed described Panamanian education as "old-fashioned." Because of receiving inadequate training, many teachers teach the same way that they were taught, with an emphasis on rote memorization rather than analysis and critical thinking. Numerous studies discredit memorization-based math learning as "ineffective" and even dangerous to the development of students' mathematical understanding (Novak, 2001, Battista, 1999).

Several of our sources said that students' lack of basic skills and inability to think critically about math can be attributed to the teachers' antiquated teaching style. Attempts to fix this are often futile, because teachers are often poorly educated themselves, and do not know how to break from the way that they were taught. As Navarro told us, "teachers can't teach what they don't know."

Because of old-fashioned teaching methods, students do not strongly learn math basics at a young age. In later grades, education builds on basic knowledge and students struggle because they have not retained the basics. In our online survey we asked teachers if they know why students struggle with math, and if so to give a reason why. Of the 14 teachers scattered across Panama who responded, 11 said that they knew why their students struggle. Of those 11, 6 teachers attributed student's

struggles to a lack of basic skills. Many of the teachers who responded to our online survey agreed that their students struggle in math because they lack basic skills. Another problem is the students' inability to solve application problems. Powell said that his students were often extremely confused when presented with application problems.

Many international standardized tests focus on application and analysis problems. As students do not learn application and analysis in class, they perform poorly on these tests.

Ideally, ASSISTments and the feedback that it provides could help turn teaching into a more interactive process. Also, ASSISTments hints could help students to work through analysis problems.

Limitations: The sample size of students we spoke to was relatively small. We also did not ask students what they thought of their teachers and teaching methods. Student opinions on this would have helped to better understand more angles.

Our survey sent to Panamanian math teachers was done online. Because of this only teachers with internet access could respond. Our sample size was limited to only 14 respondents.

Finding 2: Most Panamanian students find math to be particularly difficult, as shown by our surveys and confirmed by a more widespread survey.

Summary of Evidence:

1. 80% of the 100 middle school students that we surveyed rated the difficulty of math to be 3 or higher on a scale from 1 (very easy) to 5 (very difficult).
2. Most students (61%) that we surveyed chose math or a math-related subject as their most difficult subject, as shown in **Figure 11.**
3. According to a large survey from 2010, 44% of Panamanian students find that math is the most difficult subject (Valderrama Bahamóndez & Schmidt, 2010).

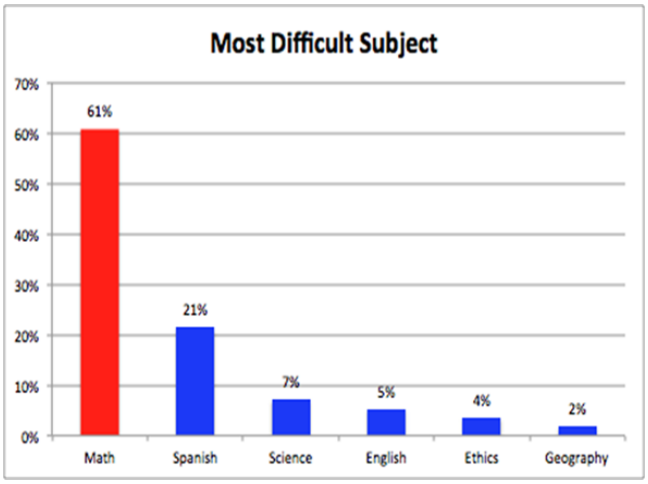


Figure 11 *Middle School Students Hardest Subject, as shown by our survey results*

Discussion/Explanation: Drawing from these survey results, it is evident that students we surveyed struggle with math in Panama. During further research, we found a survey that collected information from 300 public school students, equally divided between rural and urban schools. From this outside survey, math was most commonly chosen as a student's most difficult subject. This shows that students across Panama, not just the students at one local private school, struggle with math.

Limitations: Because we received the bulk of our data from four private school classrooms, it is only representative of a specific segment of the Panamanian population. To counter this, we looked at a similar dataset from a larger scale survey.

Because of broadly worded survey questions, our results for the question regarding students' most difficult subjects were limited to only two of our four class sections.

Objective 2: Assess Panamanian experiences and attitudes concerning educational technology.

Finding 1: Some Panamanian public and private schools have attempted to implement educational technologies such as Smartboards, Balboa Laptops, and Destino Matematico, but most have ultimately failed because of insufficient teacher training and frustrations such as losing a significant amount of class time to setting up the technology.

Summary of Evidence:

Over the course of our project, we came across the following educational technologies which have already been introduced to Panamanian schools:

1. **Smartboards**: The teachers we interviewed and worked with were in the possession of Smartboards, which are interactive projector boards. One teacher chose not to use the interactive board because it took a long time to turn on and thus took away from his class time (Serracin, personal communication).
2. **Schoology:** A local private school teacher once tried a website called "Schoology" in his eighth-grade math class. He stated that his students had loved the program, yet he chose not to use it again because he has limited class time and it took far too long to set up (Powell, personal communication).
3. **Destino Matematico:** One of Panama's past governments attempted to begin a program in schools with another educational technology program, "Destino Matematico", a math education game. According to de Vernier, the government never completed the project, and stopped supporting the teachers. Now only a handful of teachers still use it (de Vernier, personal communication). Maria Heller of SENACYT believed that that during the program's brief period of usage, student performance did see a slight increase, yet no studies were done to confirm this effect (Heller, personal communication).

4. **Balboa Laptops**: Several years ago, MEDUCA attempted to implement a program called Balboa Laptops, but the effect on student academic performance was not measured. After declining to participate in the OLPC program, Panama began a similar program with Balboa Laptops. Laptops were given to students and teachers across the Panamanian public sector. Government officials claim that the laptops improved academics because they gave students unlimited access to information. According to Heller, the laptops ultimately did not increase student learning. Teachers were taught how to use the laptop for three weeks. They were instructed in basic programs such as Microsoft Word, internet searches, and e-mail. Teachers were not taught to use the laptops for teaching. While students benefited from the laptops, since knowledge in basic computer skills is necessary for success in the competitive job market, there is no concrete evidence that they performed any better in school (Heller, personal communication).
5. **Khan Academy**: SENACYT is currently running a program using Khan Academy to review basics with 400 elementary school teachers, and plan to implement it in classrooms next year. The program has a more qualified teacher (master's degree) giving lessons through Khan Academy to less qualified teachers. These lessons are meant to refresh the teachers on their basics of the subjects. Many teachers found Khan Academy to be useful to improving their learning and intend to participate in next year's program using the website in student classrooms (Heller, personal communication).

Discussion/Explanation: Most of these educational technologies had limited success because of the following reasons:

1. **Brief programs**: Due to government turnover, many programs are begun but not completed.
2. **Overuse of Class time**: Classes in Panama are short, sometimes only 30-45 minutes. Teachers found that time takes for setting up computers and wireless internet for an online assignment, or setting up Smartboards could take up to half of the class time.
3. **Insufficient Training:** Often, teachers did not receive enough training and thus did not fully understand the technology and how to efficiently use it.
4. **Insufficient Support**: Programs instituted by the government often lacked significant support. As a result, teachers sometimes encountered frustrations such as technical bugs, and abandoned the technologies as a result
5. **Limited Equipment**: Public schools students infrequently use computers as part of their education because there are very few computers available. Schools often have too many students and not enough computers. Worse, the computers often break, or are stolen (Valderrama Bahamóndez & Schmidt, 2010).

Understanding these experiences helped us avoid the same problems in the ASSISTments trial. We provided substantial teacher training before the trial and support throughout the trial to avoid making the same mistakes.

Limitations: Our data is based on information from of a limited selection of teachers from a narrow range of schools.

The information from about government programs is not complete. We were not able to access any official reports or records, so all of our information is from personal accounts from only a couple government officials. We were not able to receive full explanations on specifics of successes and limitations of other attempted educational technologies due to government corruption. Different organizations had different biases. It was not possible to get into contact with many members of previous governments to obtain first-hand experience on several technologies. Thus, we could not fully understand what had gone wrong.

Finding 2: Of the 100 seventh- and eighth- grade private school students that we surveyed, nearly all of them would be willing to try an educational technology.

Summary of Evidence: From the surveys given to the students in our trial classes, we determined that an overwhelming majority of students, 94%, wanted use educational technologies. This can be seen in **Figure 12**. In the pre-ASSISTments survey, 9 of 10 students said that they have used educational technologies in math class before. However, when later asked if they had used anything similar to ASSISTments before, almost all students said no.

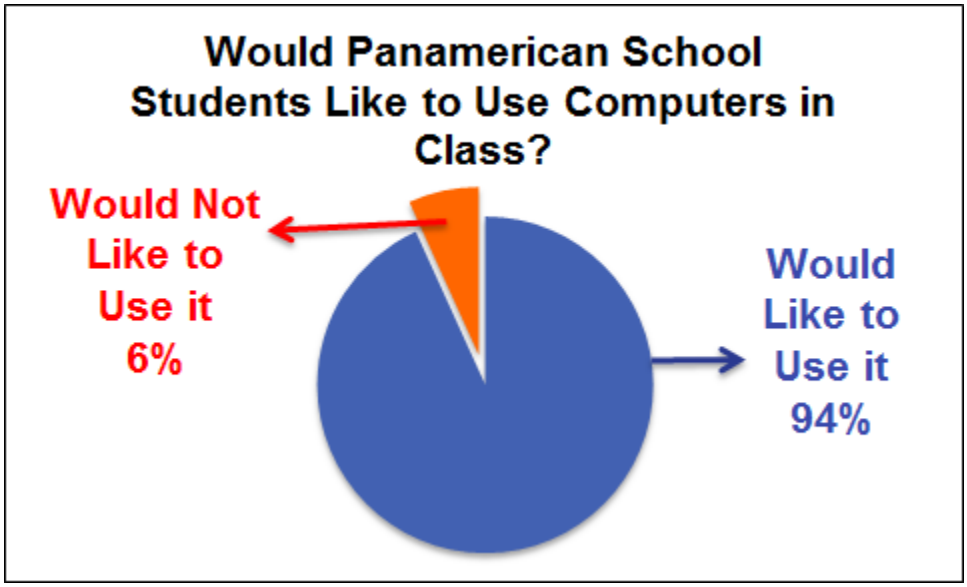


Figure 12 *Student interest in using computers in class, as shown by our survey*

Discussion/Explanation: Students appeared to be enthusiastic towards using educational technology. We assume that many of the students who have already used educational technology likely had a positive experience with it because they are interested in using it again. However, it is likely that the technologies students has used before included projectors and Smartboards, and not computer

software. Students' opinions towards educational technology influence their reactions to the program and assignments given.

Limitations: This sample was not representative of the entire population, thus our data is not.

We obtained this data only from the four class sections that we worked with. As private school students, these students are not representative of the entire Panamanian student population. These students are in an environment where technology is much more available than in many public schools. Our knowledge of students' experience levels with education technology is limited to Panamerican School.

In our survey, we did not clarify what kinds of technologies we were asking students about. The term "educational technology" is very broad. Students may have had different opinions on what was considered an educational technology. Some may have answered 'yes' with technologies such as simple projectors in mind. This may have skewed our data, showing more students claiming to have used an educational technology before, when they had not by our more specific definition of educational technology.

Objective 3: Develop a feasible, efficient, and scientific trial to test ASSISTments in a Panamanian middle school.

Finding 1: Rather than a true experimental design that is neither feasible nor ideal (due to randomized groups), a quasi-experimental design in which non-random control and experimental groups drawn from pre-existing classes are given identical pretests and posttests is the most feasible trial design.

Summary of Evidence: After reading through *Research Methods in Education*, a textbook on designing educational experiments, we found that of the three major trial designs (true experimental, quasi-experimental, pre-experimental) the quasi-experiment best fit our trial. This design contains an experimental and a control group which are both tested and observed. The other two designs were not feasible for this trial. The quasi-experiment contains a control and experimental group, unlike the pre-experimental design, where there is no control group. In a true experimental design, the groups are randomly selected, whereas the quasi experimental design has nonrandom control and experimental groups.

Discussion/Explanation: Both groups are observed and given an identical pretest prior to the start of the trial. The experimental group is given the treatment, and the control group is not. Afterwards both are given an identical posttest. The results of the tests can then be compared to show the effects of the treatment. Throughout the trial both groups are observed, interviewed, or surveyed as needed. In **Figure 13**, the O represents observations and tests, while the X represents the treatment (use of educational software) (Joy, 2007).

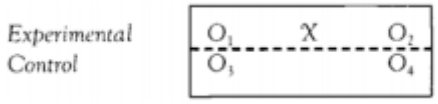


Figure 13 *Graphic explaining the quasi-experimental design. "O: represents observations and test. "X" represents the 'treatment', here being ASSISTments usage (Joy 2007).*

The quasi-experimental design was most feasible. The Panamerican school had two sections (7A and 7B) being taught the same material by the same teacher at different times. This enabled us to label an experimental group (7A) and a control group (7B). As we had to use the pre-existing nonrandom classes, we could not use the true-experimental design.

Limitations: The textbook that we used to find the quasi-experiment was our only major resource. We relied heavily on the accuracy of the trial design. Although this textbook is dependable, it limits us to only the experimental designs that it gives. There is potential of a better trial design in other sources that we were unable to obtain.

Objective 4: Analyze the implementation of ASSISTments in schools, as shown through both test scores and student/teacher opinions.

Finding 1: After using ASSISTments, average student test scores were 10% better than the class average of all tests taken in the previous trimester, whereas the control section saw no significant improvement.

Summary of Evidence: Out of 26 students using ASSISTments, 20 students did better on the posttest than their averages on the tests of the previous trimester (II Trimester). The class average on the posttest was .5 (out of 5) points, or 10%, higher than the class average on tests from the previous trimester (II Trimester). The control group saw only a .1 (out of 5) point, or 2%, increase on the posttest than their average test performance from the previous trimester. Pretest results were identical between the two classes, proving that neither class had more previous knowledge on the topic. The graph of test results can be referenced in **Figure 14.**

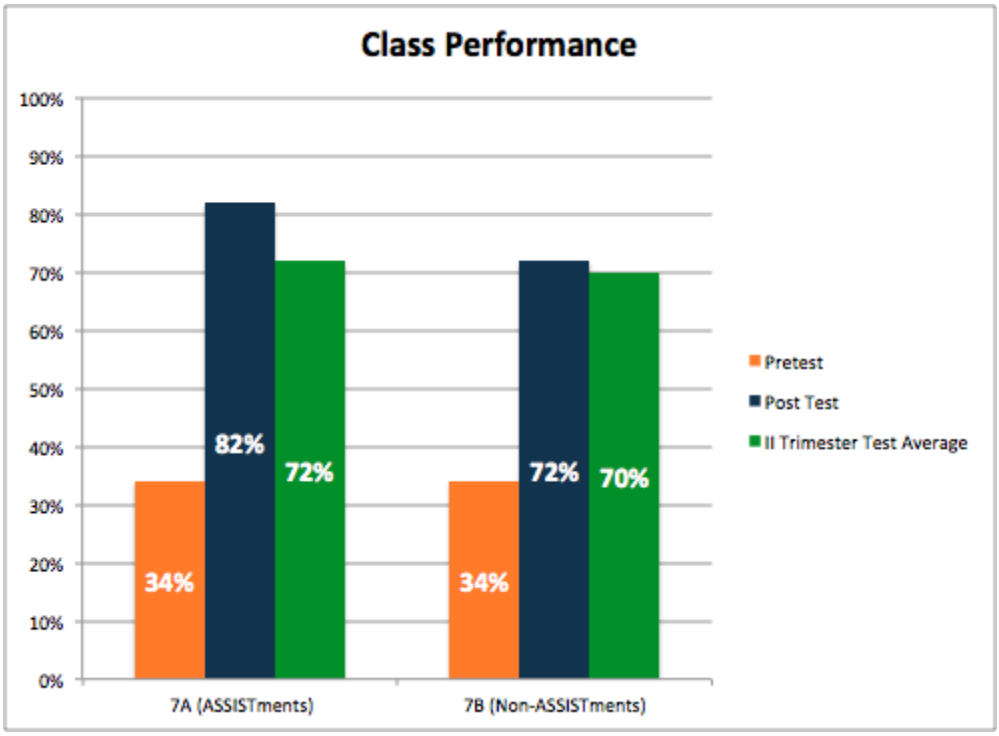


Figure 14 *Comparison of test results after ASSISTments trial*

Discussion/ Explanation**:** Overall, the experimental section saw more improvement in test scores than the control section. In previous trimesters, both sections performed roughly the same on tests. Both sections performed the same on the pretest proving that neither section had previous knowledge on the topic. The experimental section averaged 4.1 (of 5), or 82%, on the posttest, while the control section averaged only 3.6 (of 5), or 72%. Without considering our limitations, it appears as though ASSISTments may have increased student math performance.

Finding 2: The teacher believes that ASSISTments increased his time efficiency and has such a strong positive opinion that he is already using it in his other class sections.

Summary of Evidence: The seventh-grade teacher believed that the program was not a large time investment to learn and did increase the efficiency of his class. The seventh-grade teacher thought that the ASSISTments feedback was very valuable to teaching. He also thought that ASSISTments would be valuable and useful in any school that has the necessary facilities for it. The seventh-grade teacher plans to continue using ASSISTments in class. Immediately following the trial, he set up the control section to begin using ASSISTments for their homework. **Figures 15** and **16** show the difference in workshop review between the experimental and control class sections.

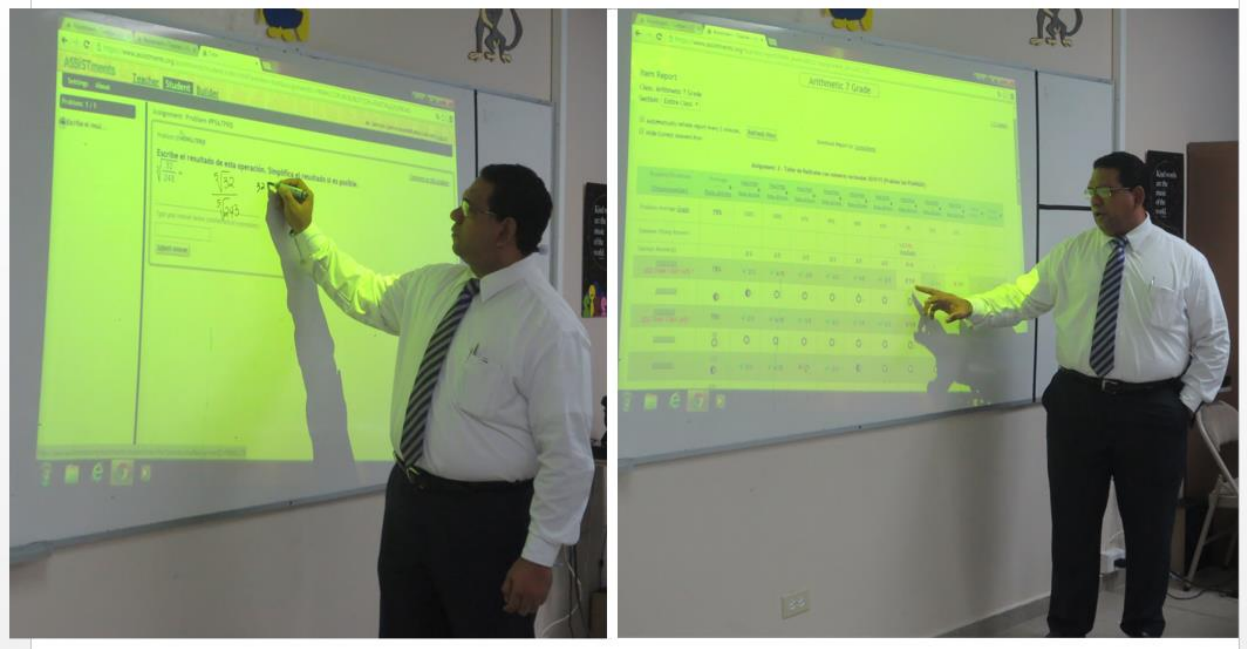


Figure 15 *Workshop review using ASSISTments feedback*

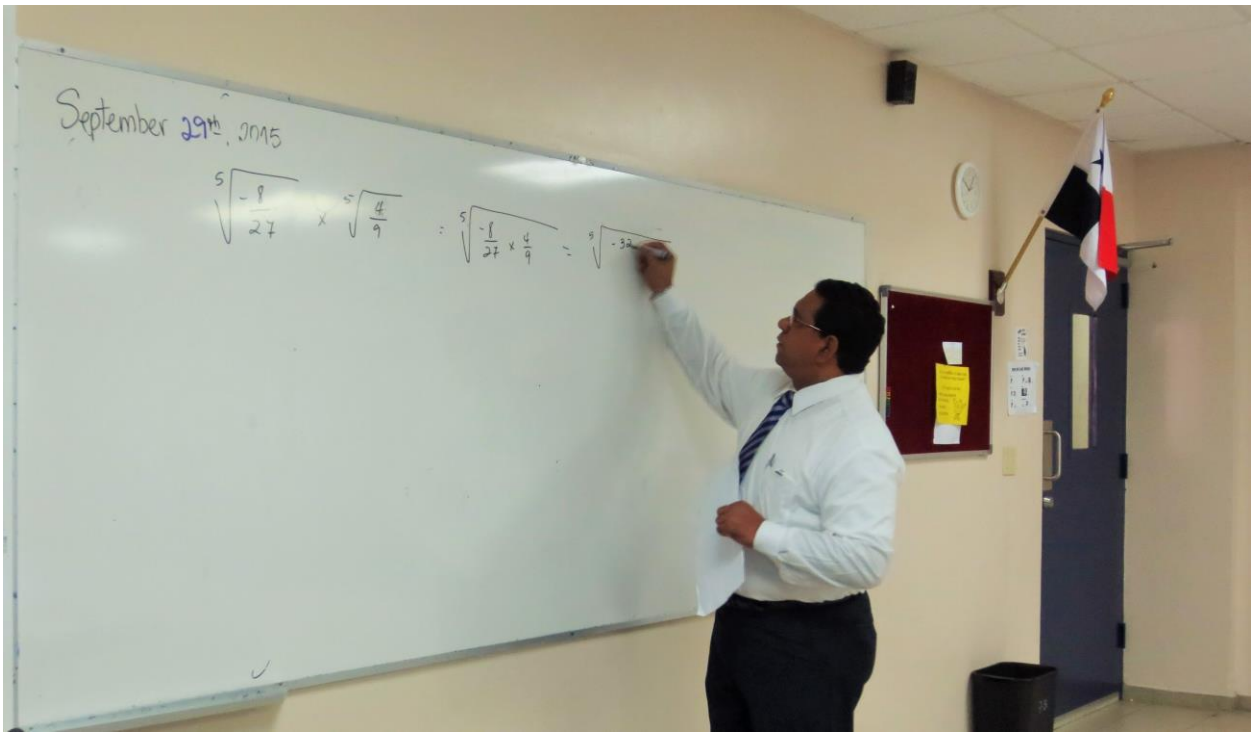


Figure 16 *Workshop review done traditionally*

Discussion/Explanation**:** We originally intended to focus on the effect of ASSISTments on the teacher's time efficiency, but since we could not develop a feasible way to test time efficiency, all we had to base our conclusions on was the teacher's opinion. The seventh-grade teacher claimed that ASSISTments was easy to learn, possibly because of the six hours we spent training him and planning the use of the website for his specific class. After two weeks of using ASSISTments in class, the seventh-grade teacher valued its feedback and intended to continue using it in his classroom. He plans to try it out for homework. He found that using it for classwork did not increase student engagement. It was difficult to get students to bring laptops every day because they are not used to doing so. Students would also use their laptops for other activities, causing an additional distraction. There was also poor internet connection at the school which made using ASSISTments for classwork to be less than ideal.

Limitations: It was difficult to get concrete result for time efficiency. If we had determined a method of feasibly testing it our result would have been more reliable than one opinion.

Finding 3: The majority of students believed that ASSISTments was a useful tool that increased their engagement in math class, and all of them thought that other students would like using it.

Summary of Evidence: 86% of students (18 out of 21) claimed that they were more engaged in class when using ASSISTments. In contrast, the seventh-grade teacher did not feel that the class was more engaged when using the program. When asked to rank ASSISTments usefulness on a scale from 1 (not useful) to 5 (very useful), 86% of students (19 of 22) selected a 4 or 5. 14 out of 22 students, roughly ⅔, said they performed better when using ASSISTments in math class. All other students said they performed the same. No students claimed to perform worse. All students also stated that they thought that students at other schools would also like ASSISTments. Pictures of a student using ASSISTments and the ASSISTments class section can be found in **Figure 17** and **Figure 18.**

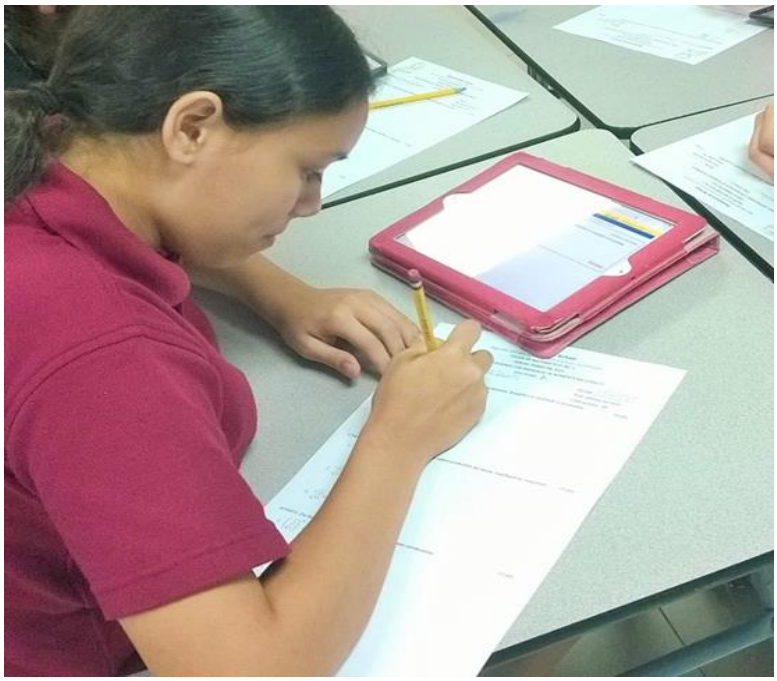


Figure 17 *A student works on her workshop assignment using ASSISTments*

Figure 18 *The class section who used ASSISTments is pictured here with two members of our team*

Discussion/Explanation: Like teacher time efficiency, student engagement was difficult to measure. Purely based on student opinions drawn from our survey, ASSISTments was more engaging. From the teacher perspective, students were no more interested and engaged in their classwork than usual when using the program. Overall, students had largely very positive opinions on ASSISTments. Many felt that it was useful to their learning.

Limitations: Student engagement was difficult to reliably measure. The teacher view and student view were conflicting.

Trial Analysis and Conclusions

While student test scores did improve, and both students and teachers have positive opinions on ASSISTments, many limitations make us question the validity of our trial. What follows is a list of our trial's most significant limitations:

1. Class topic: We only tested one class topic, which is not indicative of increased learning as a whole. It is entirely possible that ASSISTments could have been more or less useful for other topics. It is also possible that the experimental section grasped the concept of radicals more easily than the control section, regardless of ASSISTments usage. Testing a wider range of topics would better validate the effect of ASSISTments on grades.

   Since we only tested one topic, the students may have found the topic easier, swaying their opinions on the program. A harder topic may have resulted in more negative opinions of the program.

   In analyzing test score results, we compared the posttest results to the average over the entirety of the previous trimester. A more accurate determination would have been to compare an average of an entire trimester of ASSISTments usage to an entire trimester without usage. This could have been possible with more time.

2. Feedback/trial set-up: The class did not take advantage of the unique features of ASSISTments as much as we would have hoped, arguably making it no different from traditional paper work. In the daily ASSISTments problems the students had access to hints, but the teacher did not review the results of these problems using ASSISTments or adjust his teaching. During the class-long "workshop" students did not have hints, but the teacher reviewed the assignment using ASSISTments feedback. He attempted to focus on the problems that students particularly struggled with in a review session the next day. Though there was a slight additional focus on problems that the students found difficult, we observed that there was little difference in how the teacher taught the review session from in the control. The teacher agreed that his teaching style did not change much, but did think that the data from every ASSISTments assignment was still valuable to his understanding of each student's learning.

   The teacher understood the benefits of the ASSISTments feedback, but did not use it to its full potential. Because the workshop was a group assignment, the teacher could not conclude that every student getting a problem correct actually understood it. He could not focus his review only on the problems that the feedback showed were the most difficult. Our trial was too

short to include more assignments, and thus more in-class review that would allow for the feedback to be used to its full potential.

3. Change in routine

   Related to new methods of learning: Students may have been influenced by the change of their everyday learning routine. The students using ASSISTments not only had to learn a new topic, but also a whole new software which have impacted their grades. Because students were likely intrigued by the change in their routines, they may have been more engaged in classwork, and thus learned the topic better. Testing out more topics over a longer time period would show if ASSISTments impacted their learning once it had become routine in the classroom.

   Related to our presence: Students may have been influenced by our presence in their classrooms. This may have affected their behavior, class performance, or interest in ASSISTments.

4. Computers: When talking to students after the trial, many said that they enjoyed using computers in classrooms. This led us to question whether their improved test scores were specific to ASSISTments. It is possible that the use of any computer program would have caught students' attention, thus showing improvement in test scores and positive opinions.
5. Sample size: Only one class of 24 students used ASSISTments. These results cannot be generalized to all Panamanian schools, or even just the entirety of the Panamerican School. Because we could not complete the trial with the eighth-grade geometry class, our sample size was small and uniform. Other Panamanian students may have reacted differently to ASSISTments. At the end of the trial, we had only one teacher's opinion on ASSISTments, which cannot represent Panamanian teachers as a whole. The eighth-grade math teacher was an advocate of educational technology before the trial. Teachers who are skeptical of educational technology may be more likely to focus on the negative aspects of ASSISTments and any difficulties rather than on the positive aspects.

Many of these limitations were inevitable because of the two week time frame. We cannot say for sure that the increase in student test scores or the positive reception to ASSISTments was entirely because of ASSISTments and not one of these many other influences. Ultimately, our trial is inconclusive because our various limitations.

Chapter 5: Conclusions and Recommendations

Conclusions

Through research, interviews, and our trial, we gained the following insights into Panamanian math education and attempts to introduce educational technology such as ASSISTments:

1. Because most teachers, particularly in primary school, have received inadequate training, they generally teach using "old-fashioned" methods, focusing on rote memorization, thus undermining students' basic skills, retention levels, understanding of math applications and analysis, and test performance.
2. Most Panamanian students find math to be particularly difficult, as shown by our surveys and confirmed by a more widespread survey.
3. Some Panamanian public and private schools have attempted to implement educational technologies such as Smartboards, Balboa Laptops, and Destino Matematico, but most have ultimately failed.
4. Of the 100 seventh- and eighth- grade private school students that we surveyed, nearly all would be willing to try an educational technology.
5. Rather than a true experimental design that is neither feasible nor ideal (due to randomized groups), a quasi-experimental design in which non-random control and experimental groups drawn from pre-existing classes are given identical pretests and posttests is the most feasible trial design.
6. After using ASSISTments, students' average test scores were 10% better than in the previous trimester, whereas the control section saw no significant improvement.
7. The teacher believes that ASSISTments increased his time efficiency and has such a strong positive opinion that he is already using it in his other class sections.
8. The majority of students believed that ASSISTments was a useful tool that increased their engagement in math class, and all of them thought that other students would like using it.

While student test scores did improve, and both students and teachers have positive opinions on ASSISTments, we encountered many limitations which makes us question the validity of our trial.

Recommendations

I. Recommendations for ASSISTments creators

1) To make ASSISTments an appealing program to more schools, especially those in the developing world, we recommend the Heffernan team consider the following changes to the program:

General Changes:

1. A space for students to include their scratch work: Teachers wanted to see student work in order to assess their learning. Through the program, teachers can only see final answers, meaning that students still need to turn in separate paper work. The teachers that we worked with wanted to see the students' work through the program.
2. An option for weighted grading: Teachers found that the program would better reflect their traditional teaching if there was an option to make more difficult, crucial, or extensive problems hold more weight in the student's overall assignment percentage.
3. The ability for students to message/chat their teachers: Teachers thought it would be better if students had the ability to send the teachers messages through ASSISTments. If students needed help for classwork they could call the teacher over through this. If they were doing homework, students could send the teacher a message immediately while they were working and not have to wait until class the next morning when they may forget. Students could also ask for a quick clarification in the form of a return message from a teacher. The teacher could message back to respond if they did not understand the questions.
4. The option for a time limit for assignments to be completed: Teachers wished they could put a limit of time for the student to finish the assignment once he or she had begun. ASSISTments already contains an option to set a due date and time, but teachers were interested in a 'countdown' that would start from when the students first began an assignment.
5. A more user-friendly builder tab: The team found the builder tab to be complicated to use. It could be improved by allowing the option of more detailed editing from the original assignment creation page. Currently, the assignment must be saved and then the specific problems must be further to edited in order to add more hints and buggy messages. Also, the assignment must be saved and then re-opened in edit mode in order to have an assignment longer than five problems.

Specific to developing countries:

1. The option of non-US time zones: All offered time zones are US. The appeal of ASSISTments to other countries will be lessened if they must adjust for an incorrect time zone.
2. A version that is available offline: ASSISTments is convenient where internet is prominent, but not in developing countries where working internet is more scarce. More Panamanian schools would have the ability to use the program if they were offered an offline version.
3. The option for languages other than English: Given their unfamiliarity with English, public schools were incapable of using an English-based program. Though teachers could translate

problems to Spanish using the problem builder, the entire interface is still in English. If ASSISTments is to expand beyond English speaking countries, other languages will be necessary.

4. Better organization of the content folders: Other countries curriculums do not follow the same curriculum by grade that the USA does. To make ASSISTments more appealing on an international level, it may be beneficial to have the primary organization of the content to be by topic, and not by grade.

II. Recommendations for follow up projects:

1. We recommend that the Panamanian government (AIG, SENACYT, or MEDUCA) replicate our trial, taking steps to avoid the variables that we encountered, such as sample size limitations and time constraints.

Because our trial showed improvement in student test scores, but had numerous limitations, we recommend that ASSISTments is tested more thoroughly with a similar trial to validate our findings, making the following extra considerations:

1. Choose Teachers With Varied Computer Competence: The teachers that we worked with were experienced with computers. A more realistic trial would include teachers with varying levels of computer competence, though as in our trial, teachers should receive the training necessary to both understand ASSISTments and how to incorporate it into their curriculum.
2. Spend More Time in Class/Lengthen the Trial: Make the trial run for more weeks and more class hours for each section. Running the trial for an entire trimester would be ideal. With more time spent with students, two things will happen. First, students will become more familiar with ASSISTments and can focus their learning on the classwork and not the new website. Second, the students would become more comfortable with the representatives running the trial. New people, and changes in students' routines make classes rowdier. Students will likely calm down and focus better once ASSISTments is routine for them.
3. Cover More Topics: Testing just one topic does not necessarily show the effect of ASSISTments. Student improvement or lack thereof could be because that topic is significantly more difficult or easier than past topics. Looking at improvement over a wider range of topics would remove this variable.
4. Even Experimental and Control Class Sections: The trial would be better run if the two class sections are as close to identical as possible. When one section has a stronger starting point than the other it is more complicated to compare the sections. This applies to both academic performance and concentration levels of the class. Differences in schedule could also result in inequalities, so the two sections should meet at as close to the same times as possible.
5. Use Teacher Feedback More: One of the major advantages of ASSISTments is the valuable feedback the teacher receives. Using ASSISTments briefly in class does not seem to promote feedback use. Trying out ASSISTments as homework may result in better performance. This way, the teacher can use the feedback from homework assignments to tweak the next day's class so that students' will get the most out of it.

We recommend the Panamanian government run the trial again with these recommendations with ASSISTments in at least four different schools. More variety in students and teachers will yield more complete and reliable results.

2. We recommend that the Panamanian Government (AIG, SENACYT, or MEDUCA) runs a similar ASSISTments trial in public schools, taking into account both the problems that our trial encountered and the following special considerations for public schools:

We were not able to test ASSISTments in public schools in this project due to several complications, but we recommend it is attempted in a setting where it can be the primary focus. The reasons we did not use a public school are that often there are inadequate facilities (computers and internet), and a language barrier. The following is a list of the problems that we expect to encounter in a public school, and considerations on how to address each problem:

1. Facilities may be limited: Public schools and public school students are far less likely to have sufficient access to computers and the internet than the private school that we worked with.

   PISA 2018 will be an entirely computer based exam. Thus, the Panamanian government is working to rapidly expand public school facilities to provide computers and internet. If they are successful, an ASSISTments trial in public schools would be feasible.

2. Teachers may not have as much background knowledge or enthusiasm: The teachers in our trial were well educated, experienced with technology, and extremely enthusiastic about educational technology. As a result, it was fairly easy to teach them how to use ASSISTments and how to incorporate it into their curriculum. It is possible that teachers in public schools will not be as prepared or enthusiastic to work with ASSISTments, so more thorough training may be necessary before they incorporate it into their classrooms.
3. The language barrier will be more of a factor: The school we worked with was a bilingual school. Most public schools do not use English as much, if at all. The lack of English knowledge would remove the option for the teacher to use pre-made content on ASSISTments. Content can be written in Spanish, but this is a larger undertaking for the teacher, particularly a teacher who is not confident with technology yet. Also, the interface itself is entirely in English. A few ways to possibly overcome the language barrier are:
   a. Several public schools have begun bilingual programs in the younger elementary grades. ASSISTments could be tailored to and tested on a class of younger students in a bilingual program.
   a. ASSISTments could be translated to overcome the language barrier.
   b. Several public schools were under the impression that ASSISTments was meant to teach English as a second language to students. Although this was not its original purpose, this could be an idea for a further project to explain the program to public schools through this method.

3. We recommend that the Panamanian government (AIG, SENACYT, or MEDUCA) develop similar trials with educational technologies other than ASSISTments.

ASSISTments is not perfect, and other technologies may be more beneficial. It could be of great benefit to test different educational technologies that have different purposes to see their impact on Panamanian education. The following is a brief list of educational technology categories that the Panamanian government could test:

1. Interactive educational game: The anticipated benefit from an interactive game is student engagement. Students may find a game fun or exciting, increasing their engagement, and by extension, their learning. The intended age for this program can vary depending on the simplicity, and context of the game. A trial on this educational technology would help determine how much student engagement factors into test scores.

   From our understanding, the Panamanian government has already run a program to introduce a math game called Destino Matematico into schools, but never attempted to measure its effects on student learning, and has since abandoned the program. We recommend that the Panamanian government test the effects of Destino Matematico or a similar educational technology.
2. Website where notes and videos can be posted: Another useful educational technology to test would be a website where the teacher can post notes and videos to help students while they do not have access to the teacher. This website can help students while they are completing homework. Rather than getting stuck on a problem, the student can go on the website and use what the teacher posted as assistance.
3. Messenger for student and teacher communication: If a student needs to have a question answered on short notice, the teacher and other students can communicate to help one another. A tool such as this could make communication fast and easy.

4. We recommend that the Panamanian government (AIG, SENACYT, or MEDUCA) institutes a program to both train and support interested teachers with the necessary facilities who want to use technology in their classrooms.

Educational technologies in Panama tend to fail because of insufficient training and frustrations. Some teachers are interested in educational technology, but lack the time and support to properly implement it in their classrooms. We believe that they could be successful if a government program introduces an educational technology with the proper amount and quality of training and support. The following are considerations for such a program:

1. Inviting teachers: The program should start by inviting teachers with proper facilities, then accepting the teachers who show interest. The program must not be compulsory, because if uninterested teachers are forced to change their curriculums, the program will inevitably fail.
2. Training process: We recommend that a trainer who works with the teachers in person administers the program. This trainer will guide teachers through the implementation process by teaching them how to use the educational technology properly. The trainer's presence and approval should build the teachers' confidence and allow for questions to easily be answered.

After a teacher is acquainted with the basics, he or she can begin to adapt the tool to his or her curriculum.

3. Support: Once the educational technology is implemented in the classroom, the trainer must give the teacher all the support required. In the weeks immediately following classroom implementation, teachers should be able to speak to a trainer multiple times per week. The teachers will likely encounter frustrations such as technical bugs, and may abandon the tool without proper support.
4. Program length: Training a teacher should take between one and three weeks, depending on both the teacher being trained and the educational technology being implemented. This is based on our trial, where the teachers were comfortable with the basics of ASSISTments after a 2 hour training session and were able to develop a basic curriculum for the next two weeks of class after two more 2 hour sessions. It is important that the training process takes all of the time required for teachers to learn the program.

    We recommend that support for the teachers last for at least a full trimester. We consider this to be enough time for the teacher to be fully acquainted with the educational technology.

Project Design Principles

In completing this project, we learned two important lessons about problem-solving, and the integration of technology into the unique culture of a foreign country:

1. Nothing is more valuable to projects with a language barrier than clear, direct communication both within the group and with group contacts.

Throughout our project, we encountered numerous situations where miscommunication hindered our progress. Even with a team member who is a fluent Spanish speaker and Panamanian citizen, the language barrier was a significant problem when communicating with other Panamanians. Sometimes ideas needed to be explained several times in both English and Spanish among members of the group and contacts so that everything was understood.

We also learned that just because a contact speaks English it this does not mean that they will fully understand ideas as well as they do when they are explained in Spanish.

2. Careful wording of interview and survey questions will help yield more accurate/reliable data.

Our team worked with people who varied in age and English experience. Depending on the context of the question and who was being asked, we had to change the phrasing. When interviewing an adult who spoke English as a second language, questions needed to be simple and concise. We also needed to speak slowly and sometimes repeat the questions. When working with middle school students, survey questions had to be worded carefully. Even when we accounted for leading questions and potentially biased responses, we still found that some of our results were skewed by unexpected effects.

Works Cited

Albirini, A. (2006). Teachers' attitudes toward information and communication technologies: the case of Syrian EFL teachers. *Computers & Education*, *47*(4), 373–398. http://doi.org/10.1016/j.compedu.2004.10.013

Arroyo, I., Wallace, R., Beal, C. R., & Woolf, B. P. (2003). Tutoring for SAT-math with Wayang Outpost. Presented at the Advanced Technologies for Mathematics Education Workshop.

Banerjee, A., Cole, S., Duflo, E., & Linden, L. (2005). *Remedying education: Evidence from two randomized experiments in India*. National Bureau of Economic Research.

Bdelaney. (2014, April 27). Blended Learning with Mrs. Delaney: Using ASSISTments in my Blended Learning Classroom! Retrieved from http://blendedmathlearning.blogspot.com/2014/04/using-assistments-in-my-blended.html

Beuermann, D. W., Cristia, J. P., Cruz-Aguayo, Y., Cueto, S., & Malamud, O. (2013). *Home computers and child outcomes: Short-term impacts from a randomized experiment in Peru*. National Bureau of Economic Research.

Bhuasiri, W., Xaymoungkhoun, O., Zo, H., Rho, J. J., & Ciganek, A. P. (2012). Critical success factors for e-learning in developing countries: A comparative analysis between ICT experts and faculty. *Computers & Education*, *58*(2), 843–855. http://doi.org/10.1016/j.compedu.2011.10.010

Challenges for Education With Equity in Latin America and the Caribbean. (2011) (Vol. Draft Report N° 6). Presented at the United Nations Economic and Social Council Annual Ministerial Review, United Nations Economic and Social Council. Retrieved from http://www.un.org/en/ecosoc/newfunct/pdf/6.challenges.for.education.with.equity.web.pdf

Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review*, *9*, 88–113. http://doi.org/10.1016/j.edurev.2013.01.001

Chubon, B. (2015, May 27). *The effects of online homework on achievement in college preparatory mathematics classes* (Thesis). Retrieved from http://scholarworks.csustan.edu/handle/011235813/885

COMPARISON OF RESULTS BETWEEN THE SECOND AND THE THIRD REGIONAL COMPARATIVE AND EXPLANATORY STUDIES. (n.d.). Retrieved from http://www.unesco.org/new/fileadmin/MULTIMEDIA/FIELD/Santiago/pdf/Firts-Release-results-TERCE.pdf

Federal Research Division, L. of C. (1987). *A Country Study: Panama*.

Heffernan, C. (2015). personal communication. Email.

Heffernan, N. T., & Heffernan, C. L. (2014). The ASSISTments Ecosystem: Building a Platform that Brings Scientists and Teachers Together for Minimally Invasive Research on Human Learning and Teaching. *International Journal of Artificial Intelligence in Education*, *24*(4), 470–497.

Hudson, S., Kadan, S., Lavin, K., & Vasquez, T. (2010). *Improving Basic Math Skills Using Technology*. Retrieved from http://eric.ed.gov/?id=ED512698

IMO Results. (n.d.). International Mathematical Olympiad Foundation. Retrieved from https://www.imo-official.org/results.aspx

Jere-Folotiya, J., Chansa-Kabali, T., Munachaka, J. C., Sampa, F., Yalukanda, C., Westerholm, J., … Lyytinen, H. (2014). The effect of using a mobile literacy game to improve literacy levels of grade one students in Zambian schools. *Educational Technology Research and Development*, *62*(4), 417–436. http://doi.org/10.1007/s11423-014-9342-9

Joy, M. (2007). *Research methods in education*. The Higher Education Academy Innovation Way, York Science Park, Heslington, York YO10 5BR. Retrieved from http://dspace.utamu.ac.ug:8080/xmlui/bitstream/handle/123456789/151/%5BLouis_Cohen,_Lawrence_Manion,_Keith_Morrison%5D_Res(BookFi.org).pdf?sequence=1&isAllowed=y

Kraemer, K. L., Dedrick, J., & Sharma, P. (2009). One laptop per child: vision vs. reality. *Communications of the ACM*, *52*(6), 66–73.

Lambert, T. (2013). A BRIEF HISTORY OF PANAMA.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). *Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies*. US Department of Education. Retrieved from http://eric.ed.gov/?id=ED505824

Panama- The World Bank. (2015, April 12).

PISA 2009 at a Glance. (n.d.). Retrieved from http://www.oecd.org/pisa/46660259.pdf

Razzaq, L., Patvarczki, J., Almeida, S. F., Vartak, M., Feng, M., Heffernan, N. T., & Koedinger, K. R. (2009). The ASSISTment Builder: Supporting the life cycle of tutoring system content creation. *Learning Technologies, IEEE Transactions on*, *2*(2), 157–166.

Richardson, U., & Lyytinen, H. (2014). The GraphoGame Method: The Theoretical and Methodological Background of the Technology-Enhanced Learning Environment for Learning to Read. *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, *10*(1), 39–60.

Sonika Coomar, & Ilia Ryzhov. (n.d.). A Short Case Study of the Impacts of the OLPC Project around the World. Retrieved from https://files.ifi.uzh.ch/hilty/t/examples/IuN/Case_Study_One_Laptop_per_Child_(OLPC)_Project_Coomar_Ryzhov.pdf

The Panama Canal and the Torrijos-Carter Treaties. (2013).

The Panama Railroad Era. (n.d.).

Tomul, E., & Çelik, K. (2009). The relationship between the students' academics achievement and their socioeconomic level: cross regional comparison. *Procedia-Social and Behavioral Sciences*, *1*(1), 1199–1204.

UNESCO Millennium Development Goals: Education Counts. (n.d.). Prezi. Retrieved from http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-all/education-and-the-mdgs/

Valderrama Bahamóndez, E. del C., & Schmidt, A. (2010). A Survey to Assess the Potential of Mobile Phones As a Learning Platform for Panama. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems* (pp. 3667–3672). New York, NY, USA: ACM. http://doi.org/10.1145/1753846.1754036

VanInwegen, E. (2015). personal communication.

Woolf, B. P., Arroyo, I., & Zualkernan, I. A. (2011). Education Technology for the Developing World. In *2011 IEEE Global Humanitarian Technology Conference (GHTC)* (pp. 493–498). http://doi.org/10.1109/GHTC.2011.69

Worldpress.org. (n.d.). Colombia.

Note that our citations and bibliography are not fully organized at this time. It's possible that something's missing.

Arroyo, I., Wallace, R., Beal, C. R., & Woolf, B. P. (2003). Tutoring for SAT-math with Wayang Outpost. Presented at the Advanced Technologies for Mathematics Education Workshop.

Bhuasiri, W., Xaymoungkhoun, O., Zo, H., Rho, J. J., & Ciganek, A. P. (2012). Critical success factors for e-learning in developing countries: A comparative analysis between ICT experts and faculty. Computers & Education, 58(2), 843–855. http://doi.org/10.1016/j.compedu.2011.10.010

Challenges for Education With Equity in Latin America and the Caribbean. (2011) (Vol. Draft Report N° 6). Presented at the United Nations Economic and Social Council Annual Ministerial Review, United Nations Economic and Social Council. Retrieved from http://www.un.org/en/ecosoc/newfunct/pdf/6.challenges.for.education.with.equity.web.pdf

Cheung, A. C. K., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. Educational Research Review, 9, 88–113. http://doi.org/10.1016/j.edurev.2013.01.001

Chubon, B. (2015, May 27). The effects of online homework on achievement in college preparatory mathematics classes (Thesis). Retrieved from http://scholarworks.csustan.edu/handle/011235813/885

Harris, S. (n.d.). PANAMA'S GREAT CHALLENGE: REFORMING THE EDUCATIONAL SYSTEM.

Heffernan, C. (2015). personal communication. Email.

Heffernan, N. T., & Heffernan, C. L. (2014). The ASSISTments Ecosystem: Building a Platform that Brings Scientists and Teachers Together for Minimally Invasive Research on Human Learning and Teaching. International Journal of Artificial Intelligence in Education, 24(4), 470–497.

Hudson, S., Kadan, S., Lavin, K., & Vasquez, T. (2010). Improving Basic Math Skills Using Technology. Retrieved from http://eric.ed.gov/?id=ED512698

Jere-Folotiya, J., Chansa-Kabali, T., Munachaka, J. C., Sampa, F., Yalukanda, C., Westerholm, J., … Lyytinen, H. (2014). The effect of using a mobile literacy game to improve literacy levels of grade one students in Zambian schools. Educational Technology Research and Development, 62(4), 417–436. http://doi.org/10.1007/s11423-014-9342-9

Kraemer, K. L., Dedrick, J., & Sharma, P. (2009). One laptop per child: vision vs. reality. Communications of the ACM, 52(6), 66–73.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies. US Department of Education. Retrieved from http://eric.ed.gov/?id=ED505824

PISA 2009 at a Glance. (n.d.). Retrieved from http://www.oecd.org/pisa/46660259.pdf

PISA Data. (n.d.). Retrieved from http://www.oecd.org/pisa/46643496.pdf

Razzaq, L., Patvarczki, J., Almeida, S. F., Vartak, M., Feng, M., Heffernan, N. T., & Koedinger, K. R. (2009). The ASSISTment Builder: Supporting the life cycle of tutoring system content creation. Learning Technologies, IEEE Transactions on, 2(2), 157–166.

Richardson, U., & Lyytinen, H. (2014). The GraphoGame Method: The Theoretical and Methodological Background of the Technology-Enhanced Learning Environment for Learning to Read. Human Technology: An Interdisciplinary Journal on Humans in ICT Environments, 10(1), 39–60.

Sonika Coomar, & Ilia Ryzhov. (n.d.). A Short Case Study of the Impacts of the OLPC Project around the World. Retrieved from https://files.ifi.uzh.ch/hilty/t/examples/IuN/Case_Study_One_Laptop_per_Child_(OLPC)_Project_Coomar_Ryzhov.pdf

VanInwegen, E. (2015). personal communication.

Woolf, B. P., Arroyo, I., & Zualkernan, I. A. (2011). Education Technology for the Developing World. In 2011 IEEE Global Humanitarian Technology Conference (GHTC) (pp. 493–498). http://doi.org/10.1109/GHTC.2011.

Appendix A: The Sponsor

The Autoridad Nacional para la Innovación Gubernamental (AIG, or in English, National Authority for Government Innovation) is a Panamanian government agency established on 30 October 2009. The AIG is a government entity meant to coordinate, promote, and support the optimal use of technology with the goal of modernizing the country ("Autoridid Nacional").

More specifically, this organization seeks to recommend certain policies to lawmakers and other decision makers, public and private, with the intent of strategic planning and the optimization of information technologies. For the general welfare of Panama's inhabitants, the AIG's actions are made public and have a strong emphasis on social responsibility.

The AIG's vision of a modernized Panama involves several diverse goals. In an interview, Irvin A. Halman, the AIG's General Administrator, described the ideal culmination of the AIG's goals. Halman put a strong emphasis on the use of information and communications technologies (ICTs) as a way to reorganize Panamanian government services such as education and healthcare and to streamline government paperwork. The AIG also strives to expand the country's internet safety, taking precautions against cyber-crime and protecting e-commerce (Halman, 2013).

The AIG is subdivided into projects. Some of these projects include Modernization Project of Local Governments, National Network Internet, 311 Citizen Spotlight, and the Institute of Technology and Innovation (ITI) which will advise the ASSISTments project. The main goal of ITI is to provide awareness and apply technology to give better service to citizens ("Autoridad Nacional"). ITI is oriented towards people working in the computer science field and incorporating modern technologies into private sectors, the general public, and academia.

Appendix B: The Setting: General Information on Panama

The Republic of Panama is located in Central America between Colombia and Costa Rica. It borders the Caribbean Sea and the Pacific Ocean. Panama City is the capital of the Republic of Panama. It is 75,420 square kilometers (29120 square miles) with a population of 3,608,431 (CIA).

Panama has been diversely influenced by other countries such as Spain, Colombia, and the United States. Twelve years after being discovered by the Europeans, the Spaniard Vasco Núñez de Balboa claimed Panama for Spain on September 26, 1513. A few centuries later, Panama declared independence from Spain on November 30, 1821 (Lambert). The purpose of this independence was to join Gran Colombia, which was a super state with enormous power. It then consisted of what are now Colombia, Ecuador, Perú, Bolivia, Venezuela and Panama. In 1830 Gran Colombia collapsed, leaving Panama as part of Colombia (Worldpress.org).

The United States first influenced Panama in 1845, negotiating the construction of a railroad that crossed the country (Panama Canal Museum). Panama finally became an independent country on November 3, 1903 (Lambert). Panama then signed the Hay-Bunau- Varilla Treaty with the United States in November 18, 1903. This treaty gave the United States total power over the Canal Zone and made Panama a protectorate of the United States ("The Panama Canal and the Torrijos-Carter Treaties," 2013).

Following a failed French attempt, the United States started digging the Panama Canal in 1904. They were successful, but only after many difficulties, such as numerous deaths because of disease. The first ship went through the Panama Canal in January 7, 1914, but the canal wasn't officially opened until July 12, 1920 (Lambert). Later on, Panama signed the Torrijos Carter Treaty in 1977. This treaty guaranteed total power over the Panama Canal for the Panamanian government by then end of 20th century on December 31, 1999 ("The Panama Canal and the Torrijos-Carter Treaties," 2013).

Appendix C: Survey Questions for Students (pre-ASSISTments Trial)

Survey

Panamerican School

Arithmetic 7th

Name: _____

List Number: _____

Student Survey Questions:

1. What is your favorite subject? _____
2. What is your most difficult subject? _____
3. On a scale from 1 to 5 how easy do you find math to be? (Circle your answer)

   (Very easy) 1 2 3 4 5 (Very hard)

4. On a scale from 1 to 5, how easy do your friends find math to be? (Circle your answer)

   (Very easy) 1 2 3 4 5 (Very hard)

5. How often do you use computers? (Circle the closest answer)

   a. Less than once a month
   b. Once a month
   c. Once a week
   d. 3-5 times a week
   e. Daily for 2 hours or less
   f. 3 or more hours a day

6. Have you ever used technology for schoolwork before? (Circle your answer)

   Yes No

7. Would you like or dislike using computers in math class? (Circle your answer)

   I would like it. I would dislike it.

Appendix D: Survey Questions for Teachers

1. What level/grade do you teach? _____

2. How long have you been a teacher in the Panamanian education system? _____

3. What is your highest level of schooling? (circle the answer)
    a. some high school
    b. high school graduate
    c. some college
    d. bachelor's degree
    e. master's degree
    f. Doctorate

4. Do you teach in the public sector, private sector, or both? _____

5. When teaching, how difficult do you find it to stimulate student interest in the topic?
    (very easy) 1 2 3 4 5 (very difficult)

6. What aspects of math do you find that students struggle with most?
    _____

7. Can you name a few reasons why students struggle with math?
    _____

8. Have you ever used an educational technology in your classroom before? _____
    If yes, what technology?_____

9. On a scale from 1 to 5, how willing would you be to try an educational technology in your classroom, if given the opportunity?
    (not willing) 1 2 3 4 5 (very willing)

10. Do you have any additional comments on these questions, or other information to add?
    _____

Appendix E: Teacher Interview Questions (pre-ASSISTments Trial)

1. Did you go through the Panamanian education system yourself? Did you go to college? If so, what improvements in the system have you seen since then? Are any of these improvements related to technology?

2. What do you think about the Panamanian education system?

3. How difficult do you find it to get students interested in what they are learning?

4. How much do you find that students struggle with math, as compared to other subjects?

5. What aspects of math do you find is most difficult to teach?

6. Do you feel that you tend to have a good understanding of the errors and confusions students encounter or is it difficult to pinpoint the roots of their errors?

7. What efforts have you taken in your classroom in the past to improve student learning? Have you ever used technology in your classroom?

8. What do you think about educational technology?

Appendix F: Government Official Interview Questions

Jahir Calvo Interview Questions

Do you consent to us recording this interview so that we can keep an accurate record of it?

Background

1. Where are you from? If not from Panama, how long have you resided in Panama?
2. Please describe to us your own education history:
3. What is your official position?
4. How long have you worked in your current position?
5. Please give us a brief outline of your work history, including:

About Education Systems

1. In your experience, what are the major differences between public and private schools?
2. What has been done successfully to attempt improvements among Panamanian schools? What has not been successful?
3. How are the neighboring countries' academics? How would you compare Panamanian academics?
4. Presently, how does technology play a role in public schools?
5. Have you found that instructors are willing to adapt to new teaching methods, including technology
6. What do you find to be the benefits and the drawbacks of the use of technology in school systems?
7. You have already showed an interest in ASSISTments. What would you be aiming to accomplish from the use of this technology?
8. What are your short term and long term goals within the Panamanian education system?
9. Can you point us toward any studies done or data regarding Panamanian education's international standing?
10. Do you have anything else to add?
11. Can you recommend anyone else within the Panamanian education system that we can interview? What is their contact information?

Maria Heller Interview Questions

Do you consent to us recording this interview so that we can keep an accurate record of it?

1. Can you give us some information on your academic and professional background?
2. What do you think are the strengths and weaknesses of educational technology?
3. What educational technologies have you seen in Panama before?
4. Have you seen any educational technologies used for math before? In Panama? What was successful? What wasn't? What lessons have you learned?
5. Often these projects do not see completion or are not used by teachers for very long, why?
6. What can you tell us about Balboa laptops? What about Destino Matematico?
7. Teachers are often skeptical of educational technology. Are there any strategies that you recommend for dealing with this skepticism?
8. Do you have anything else to add?

9. Can you recommend anyone else within or affected by the Panamanian education system (educational researchers/experts, other government officials, or even teachers) that we can interview? What is their contact information?

Manuel Navarro Interview Questions

Do you consent to us recording this interview so that we can keep an accurate record of it?

1. Can you give us some information on your academic and professional background?
2. What is your opinion on the current overall math performance of students in Panama?
3. We have seen that Panama did not perform well in math on international standardized test such as PISA 2009 and TERCE 2013. Why do you think this is? Do you know of any other 'hard data' detailing math education in Panama?
4. What aspects of math education do you think may need improvement?
5. What are the strengths and weaknesses of math teaching in Panama?
6. What efforts have been taken to improve math education in Panama? (successful/unsuccessful)
7. What qualifications do teachers need to be hired? What is the hiring process like?
8. What do you think are the strengths and weaknesses of educational technology?
9. Have you seen any educational technologies used for math before? In Panama? What was successful? What wasn't?
10. Teachers are often skeptical of educational technology. Are there any strategies that you recommend for dealing with this skepticism?
11. What goals do you wish to accomplish in relation to math education during your term as department head?
12. Do you have anything else to add?
13. Can you recommend anyone else within or affected by the Panamanian education system (educational researchers/experts, other government officials, or even teachers) that we can interview? What is their contact information?

Appendix G: Survey Questions for Students (post-ASSISTments Trial)

Post-trial Survey Questions
Name:_____

1. Do you think that assignments in ASSISTments made you think more, less, or about the same about a problem than paper assignments do? Why?

_____
_____

2. Would you say that you performed better, worse, or about the same using ASSISTments? Explain.

_____
_____

3. What do you think students in other schools would think of ASSISTments? What about other ages?

_____
_____

4. On a scale from 1 to 5, how often do you feel frustrated during math class before using ASSISTments?

(Not Frustrated) 1 2 3 4 5 (Very Frustrated)

5. How often did you feel frustrated while using ASSISTments?

(Not Frustrated) 1 2 3 4 5 (Very Frustrated)

6. Out of a scale from 1 to 5, how useful you think ASSISTments was?

(Not Useful) 1 2 3 4 5 (Very Useful)

7. Were you more engaged in class using ASSISTments?

Yes No

8. Would you like to keep using ASSISTments? Explain why.

Yes No

_____
_____

9. If you selected yes in Question 8, select how you would like to keep using ASSISTments and explain why.

Homework Classwork Workshop

_____
_____

10. If you have used technology for school before ASSISTments, explain how.

_____
_____

11. Can you give us some feedback about what you liked and what you didn't like about ASSISTments?

_____
_____

12. Did you find ASSISTments to be confusing? What about it? Would you have preferred that you had more guidance using it?

_____
_____

13. Do you have any other comments about ASSISTments or our trial?

_____
_____

Appendix H: Interview Questions for Teachers (post-ASSISTments Trial)

1. Was ASSISTments an effective tool for teaching?
2. What do you think other schools would think of ASSISTments?
3. Will you continue to use ASSISTments in your class? Would you recommend it to other teachers?
4. Did using ASSISTments have an effect on your teaching style? How easy or difficult was it to change your teaching style to accommodate for ASSISTments? How much extra effort/time would you say it required to learn? To use in class?
5. Did you see an effect (either positive or negative) on your time efficiency from ASSISTments?
6. Is there anything you would change about ASSISTments to improve the website?
7. Is there anything you did not like about ASSISTments, or about this trial in general?
8. Are there any changes that you would make to the way that ASSISTments was introduced? DId you find that you were adequately taught how to use the website?

Appendix I: Complete Chart of Student Test Scores

Seventh Grade A (ASSISTments)

	Ⅱ Trimester						Ⅲ Trimester
Student# (names ommited)	Test 1	Test 2	Test 3	Test 4	Test 5	Average	**Test 1 (After ASSISTments Trial)**
1	4.3	3.8	4.7	3.2	3	3.8	4.3
2	2	2	2.8	2	2.4	2.24	3.6
3	4.7	4.7	4	4.1	4.2	4.34	5
4	3.7	2.6	3.3	2.8	4	3.28	4
5	3.8	2.8	2.6	2.7	3.4	3.06	5
6	4.4	4.1	4.8	3.8	5	4.42	5
7	4.3	4.4	4.1	3.4	4.6	4.16	5
8	4.3	3.5	3.8	3.3	4.1	3.8	3.9
9	2.8	4	4	4	3	3.56	3.7
10	2	2	3.2	2	2	2.24	2.2
11	4.3	5	4.5	3.7	3	4.1	5
12	2.5	3.1	4.1	2.4	2	2.82	3.5
13	4.4	4.6	4	4.2	3.4	4.12	5
14	3.9	4.5	4.5	4.3	3.7	4.18	5
15	5	5	4.6	4.9	4.4	4.78	5
16	2.7	2.2	2.6	2	2	2.3	4.8
17	4.7	4.1	3.1	3.7	4.1	3.94	2.7
18	5	3.5	2	3.3	3	3.36	2.6
19	5	5	4.1	4.3	4.5	4.58	5
20	3.4	3.5	3	3.1	2.6	3.12	5
21	4.8	4.8	4	4.3	3.3	4.24	4.2
22	4.3	2	3.1	3.7	3	3.22	3.4
23	3.4	2.6	3	3	3.3	3.06	2.7
24	3	3.4	2.8	2.3	4	3.1	2.5
25	4.8	4.5	4.7	4.8	4.3	4.62	5
26	4.6	3.5	4	4.1	3.2	3.88	4.7
Class Average						**3.627692**	**4.146153846**

Seventh Grade B (Non-ASSISTments)

	Ⅱ Trimester						Ⅲ Trimester
Student# (names ommited)	Test 1	Test 2	Test 3	Test 4	Test 5	Average	**Test 1 (After ASSISTments Trial)**
1	4.6	4	4.1	4	4.5	4.24	4.7
2	4.3	4.7	4.9	4	4.5	4.48	5
3	2	2.6	4	2	2	2.52	2.3
4	2.9	2.4	2.5	2	2	2.36	2.8
5	4.6	4.7	4.5	3.8	4.2	4.36	4.9
6		3.3	3.1	3.5	3.5	3.35	4.4
7	3.4	2.6	2.8	2	2	2.56	4.3
8	4.3	4.2	3.1	3.8	2.7	3.62	3.6
9	2.8	4.2	4.7	3.2	3.2	3.62	3
10	2.9	2	4.4	2.7	2.3	2.86	
11	4.2	2.2	3	2.5	3	2.98	3.4
12	3.4	2	3	2	2	2.48	2
13	5	3.4	2.6	2.5	2	3.1	4
14	3.8	4.2	4.2	2.2	3.1	3.5	4.3
15	4.6	4.5	3.5	3.2	4.3	4.02	3.1
16	4.8	2.4	4	4	4	3.84	3.6
17	4.6	4.8	4.4	4.1	3.8	4.34	3.2
18	3.2	2.7	4.2	2	2	2.82	2
19	5	4.2	4.2	3.1	4.2	4.14	4.7
20	3.5	3.7	4	4	4.4	3.92	4.5
21	3.6	3	4.5	2	3.4	3.3	3.4
22	4.5	4.4	4	4	4.3	4.24	4.1
23	3.2	4.2	3	2.1	2	2.9	2.5
24	4	3.4	4.1	2.6	2.8	3.38	3.2
25	5	4.2	4	4.3	4.5	4.4	4
Class Average						**3.4932**	**3.625**