Cultural Factors in the Implementation and Use of an Intelligent Tutoring System in Latin America

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Abstract. We report on the adaptation and use of intelligent tutoring technology that supports teaching and learning of mathematics at the middle school level (5th - 8th grade) of public schools in three Latin American countries (Chile, Ecuador and Mexico). In order to introduce technology-supported strategies into teaching practice, we have done extensive training (blended-courses) for teachers together with the development of tools that help in curricula planning, instructional design, assessment, reinforcement for lower ability students, and sharing of best practices. Even though the strategies, technologies and implementation effort were the same for all participating schools, there were successes and failures. In this study, we look into cultural-organizational issues that influence the achievement of the final goal: that is, improved mathematics learning.

1 Introduction

This paper describes an extensive experimental study performed in public middle schools (5th to 8th grade in a K-12 system) of several Latin American (LATAM) countries, using teaching strategies based on cognitive tutoring technology (CT) for math learning¹. A two-stage implementation was performed during 2009-2010 in a number of public schools in Chile, Ecuador, and Mexico². Additional extended implementation continues in Chile in the period 2011-2014.

The purpose of the endeavor is to explore strategies needed to successfully implement intelligent tutoring technology and then engage teachers in the use of it in public schools of Latin American (LATAM) countries. We develop and experiment with a pedagogical framework that, considering scarce technological resources, takes advantage of personalized student-centered activities in the computer lab and collaborative-constructivist strategies in the classroom (paper and pencil). Even though the ultimate goal is to improve math learning among students and thus the technology is student centered, our core methodology is focused on the teachers: we provide training (blended-courses) for teachers and implement teaching support tools. In the training courses, the new technology-based strategies are socialized, situated and adapted to local contexts. We want to make sure teachers feel motivated and are willing participants-leaders of the required change process. After training, we provide constant support and follow-up of the implementation in the classroom and lab.

The focus is on the tools and support activities needed by the teachers in order to adequately implement the new technology-enhanced teaching strategies (assuming that the technology has been correctly deployed³). This involves substantial change in the teacher’s attitude, motivations, activities, and plans. The teachers need training, time and support for studying and planning the new classroom-lab strategies. It involves major changes in planning, instructional design and the teaching processes itself; it is a complex task. We have

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² The plan was initially designed for experimentation in four LA countries, but one of them could not fully implement it mainly due to lack of technological resources and support from educational authorities.
³ We will see later on that this assumption is, regretfully, not correct in some cases of our experimentation.
identified that once the basic technology issues are resolved (computer labs with one functioning PC for each student, reliable local area networks, client software correctly installed, sufficient Internet access to the servers, and effective technical support), there are several cultural-organizational drawbacks that work against a successful implementation.

Before describing the implementation methodology, results and findings, we first provide a brief description of cognitive tutoring technology.

1.1 Cognitive Tutor Technology

Following the theoretical principles developed by Anderson [1], [4], a personalized digital learning system known as a Cognitive Tutor (CT) was built at Carnegie Mellon University and is maintained and operated by Carnegie Learning Inc.\(^4\) In this software, each student has a personalized “problem-solving” space, with just-in-time feedback and detailed tracking of his or her progress [11]. CT follows a personalized self-paced approach, allowing students to sequentially tackle progressively more difficult tasks. It tracks students’ progress in real time as they answer questions, ask for help and solve problems. It provides personalized feedback and hints when errors are made in key points [6].

Cognitive tutors have shown considerable potential, and evidence in the literature indicates that they are effective in improving mathematics and science problem-solving skills [5], [10]. Specific mathematics cognitive tutors have been used in large school systems (primary/secondary level) in the United States, including Los Angeles and Chicago, as well as in rural areas [2].

1.2 Cognitive Tutor Strategies

The main objective of the CT software is to provide each student with a unique, enriched environment where he/she can interact with the system by solving specific problems. Multiple graphical representations can be explored by the student for creative thinking practice [3], [9], [13].

The software presents a problem and the student is requested to work towards the solution. Instead of jumping to the final answer, the software provides step-by-step scaffolding [7]. This divide-&-conquer strategy asks specific questions, from easier to more complex, so that the student can advance at his/her own pace in the solution of the problem.

The first question in each problem presented to the student is always related to the appropriate reading of the problem narrative. This can be particularly helpful in LATAM public schools, where student’s problem solving abilities are many times hindered by their lack of reading skills. The next questions (posed by the software) guide the student towards the solution of the problem\(^5\).

The student gets feedback (positive or negative points in a roster of skills to be achieved) whenever he/she answers questions within a problem. This immediate feedback is continuously represented via a “skill-o-meter” in the interface of the tutor [8]. Based on the “skill-o-meter” we have developed a web-based tool that provides teachers with a complete view of students’ progress, both at an individual and full class scale. The teacher knows at any time where individual students are standing and thus can give them reinforcement on topics of struggle [12].

1.3 Purpose of the Study

The broad objective is to understand how an educational technology that has been successfully used in developed countries can be adapted, situated, and integrated in a human and social system of a developing region, specifically the public educational sector of LATAM countries. In this case, the teacher, classroom, school, district authorities, and parents are part of the social system. The challenge is to both redesign these social arrangements (e.g. how teachers teach mathematics, how authorities provide the necessary resources) and the technology system to fit and improve students’ proficiencies in mathematics.

The key questions are as follows: are intelligent tutoring technologies appropriate for LATAM contexts? What mechanisms and tools are needed to motivate teachers in LATAM to change their teaching practices and engage in the use of intelligent tutoring technologies? Once the technology is correctly deployed, are there cultural-organizational factors that work against the change process and appropriate use of the technology? Can the motivated teacher induce students to work with the CT technology and improve their math skills? What is the attitude of the students?

\(^4\) Cognitive tutoring technology is a trademark property of Carnegie Learning Inc.

\(^5\) There is extensive literature with thorough description of CT technology ([2], [3], [4], [6], [10]).
2 Methodology

Building from experiences in the United States, the MCT initiative seeks an important innovation: the definition and application of new teaching strategies that, based on the CT technology, are adapted to the LATAM educational context. This starts with the negotiation of change strategies with the district and school authorities. It follows with the involvement of teachers in training and instructional design blended-courses (90% of work is on-line) based on the CT. It culminates with the implementation of the technology-supported strategies in the math classroom.

Once the school authorities have provided their support and there is sufficient infrastructure and resources in the school (e.g., compliance of “entrance” requirements), teacher involvement is the most critical issue in the implementation plan. The goal is to achieve high motivation and strong commitment of the teachers towards the new technology-based strategies.

In addition to the definition of the pedagogical strategies, we took an English version of the software content and, considering cultural and contextual differences, transformed it into a Spanish version, coming up with a common structure for all the participating LATAM countries at the middle school level.

Even though the underlying theory and structure of the software tool remains the same as in the English version, contents and exercises were localized to the local cultures.

General Implementation Plan: The project’s plan focuses on training, motivating and empowering teachers (as leaders) in the use of a CT technology that has been adapted and localized for LA schools. The principal components of the plan are:

- Design of the strategies and implementation, negotiated with corresponding educational authorities.
- Adaptation of CT software modules and contents.
- Development of teachers’ support tools.
- Specialized training for math teachers and design of instructional units.
- Local implementation in selected public schools of different LA countries within a scalable pilot program.
- Creation of local learning communities and a repository of technology enhanced learning materials for mathematics.
- Assessment, data collection and evaluation study.

An initial planning-design stage was accomplished in 2009 and training-implementation activities were performed in 2009-2010 in primary/secondary schools of Chile, Ecuador, and Mexico: over 730 students and 24 teachers participated in this study. During 2011 and 2012 an extensive redesign was done based on the lessons learned in the initial experimentation. New math materials were developed to cover the full middle school (5th to 8th grade) curriculum of math, and new support tools for teachers were developed. A second experimental study is currently underway on a number of public schools in Chile: 10 schools have participated during 2013 and 30 are involved in experimentation during 2014 (the academic year goes from March to December).

Design: Public schools (as opposed to private) were chosen because of the enormous quality gap between the private and public educational system in the LATAM region. Private schools have many more resources and offer little or no opportunities to a socially vulnerable population. In each country, a district/municipality with a vulnerable population was selected which was willing and able to participate in the study. Within that district, treatment schools were randomly selected among those that did have the resources (computer labs, time for teacher training, and support from their authorities). (Some of the selected schools did drop out during the implementation due to lack of motivation, amongst other reasons.) Control schools were then selected within each chosen district/municipality.

Software Adaptation: This component focuses initially on the development of 14 lessons (comprising 54 instruction modules in the MCT software) of pre-algebra fundamentals used over a five month

\(^6\) Control schools and drop outs (including teachers and students) are not considered in these figures.
period of implementation in 5th – 8th grade. In a second stage (2011-2013), over 50 new algebra and geometry lessons were developed to cover the full middle school cycle. Activities at this stage included:

- Revision of curricula and assessment of teaching strategies used in math in each country.
- Development of CT modules and supporting documentation (teacher’s guide, student book, and exercises).
- Adjustment of cognitive tutoring modules to specific school contexts. This included changes in examples presented or language used, localized to the LATAM countries.

**Tools for Teachers:** We developed a number of software tools to help teachers plan and give their classes: a syllabus planning tool that matches up the MCT lessons with the official Ministry of Education curricula; a visualization tool that shows teaching objectives (based on proficiencies), content abstracts and problem-solving examples for each lesson in the CT software; a reinforcement tool that provides teachers a complete view of the advancement of the students in their work (with the CT) and achievement of skills, both at an individual level and class level; a generator of tests that uses a database of more than 10,000 problems with multiple types of answers (multiple choices, true-false, and short answers), and a virtual community platform for student and teacher communication.

**Teachers’ Training:** Training teachers on the new pedagogical strategies and technology was of paramount importance. This included negotiating the integration of MCT modules within the existing curricula, defining corresponding learning activities, learning self-paced pedagogies and methodologies, and monitoring and assessing students. Part of the training endeavor was devoted to working with teachers in the design of instructional units. Specialized seminars in technology management and planning were also provided to school directors. Additional training was given to technical support staff in schools.

**Pilot Implementation:** With the purpose of revising the strategies, class/lab methodologies, and contents, a small scale pilot with one or two schools per country and limited MCT lessons was first conducted during 2009 while other MCT modules were being developed. Afterwards, a full scale study was conducted during 2010. A second full-scale study is being conducted in the 2013-2014 period. The following activities are being performed during the full-scale study:

- Review of class and lab infrastructure at each treatment school, to make sure there was one computer per student, appropriate local connectivity, and Internet access.
- Teachers were provided with the corresponding support documentation.
- Email, chat, and phone support was provided to teachers during implementation.
- On a weekly basis, MCT reports (of student and course progress) and suggested remedial actions were discussed with the teachers.
- Random monitoring of classes and labs was performed periodically.

**Local Learning Communities:** This component seeks to increase the capacity of math teachers to use new forms of ICT technology to motivate students to pursue scientifically oriented careers. To do so, the project included the creation of local learning communities within and between the schools, thus stimulating the exchange of experiences and best practices. A repository of best practices was created and used to promote knowledge exchange among teachers.

**Assessment Study:** This component focuses on the assessment of project-induced changes in schools, teacher practices, and student performance in math. Pre-tests and post-tests (pencil-paper based, similar format to national tests) were conducted at the beginning and at the end of the implementation, both at treatment and control schools. Additionally, surveys and interviews were conducted to learn about motivations and attitudes (towards the MCT system) of students, teachers, and school authorities.
3 Results and Discussion

The objective of the study’s evaluation process is to determine the effectiveness of the use of an intelligent tutoring system to improve skills in mathematics for 5th to 8th graders in public schools in selected LATAM countries. However, we also wanted to understand the motivations (or lack thereof) of teachers, students, and authorities to change their teaching-learning strategies. Before discussing the preliminary assessment results, we want to mention some culturally-oriented issues that impact the implementation of the technology.

3.1 Culture-Oriented Issues

From the body of research and best practices in industry, it is well known that approximately 70% of all transformation efforts involving IT fail [14]. This is so because the organizational culture and strategies play a fundamental role that many times is not appropriately addressed: “Ultimately, people do the work that produces results”; “no new computer system ever changes deep-seated human beliefs and behaviors” [14]. In our experimentation with public schools in LATAM, we have observed several cultural challenges that greatly increase the complexity of a technology-based endeavor. These challenges, common among the participating countries, can be grouped in the following categories:

- **Pedagogical processes (teaching & learning).**
- **Organizational strategies and structure.**
- **Organizational culture (teacher’s attitudes towards change and technology).**
- **Human resources (teachers’ skills and knowledge).**
- **Technology acquisition and deployment.**

**Pedagogical Processes:** Are the actual teaching processes (in the school) adequate for improved learning? Are these processes student-centered or teacher-centered? Is there a constructivist approach or is it behaviorism oriented? Is the technology used to innovate and improve the teaching process or is it used just to micro-improve a given task (e.g., projectors for lectures, e-books for reading and computer labs for Internet searches)? In our pilot implementation, it has been very difficult to change the actual teaching processes which in general are teacher-centered and lecture style with little involvement on the part of the students. Notwithstanding, we will see that students do improve their math skills after using the CT software in the lab, regardless of classroom strategies.

**Organizational Strategies and Structure:** Are the actual structures and associated strategies adequate to motivate, lead and perform a real change in the teaching processes? In our case, the main problem refers to the complexity of the relationship between the high level (state or municipality) authority and the school principals. Most municipality authorities gladly supported the MCT initiative, but would not provide additional resources for the schools. Municipality authorities can change very rapidly for political reasons, providing discontinuities to the project. In some cases, school authorities would not provide sufficient support (e.g., extra time for training) to involved teachers.

**Organizational Culture:** When asked during our experimentation, all participating teachers agreed about the need of change in their pedagogical strategies. However, it was very difficult to implement this change in the classroom. Mostly young teachers devoted significant time to training in the new technologies and for working towards change in their methodologies, as opposed to more experienced teachers. In general, we noticed a widespread lack of confidence in the value of new technology-based strategies.

**Technology Acquisition and Deployment:** Even though this obstacle relates to technology, there were organizational-cultural aspects that affected the deployment of the technology. For instance, several of our participating school principals were buying tablets for their students, but have not yet decided how they were to be used. How is the teaching process going to be changed to take advantage of the new technologies? Are there enough local area networks (e.g., Wi-Fi) to support the use of the new technology? Is there a sound Internet connection and Web services? Does the school have technical support? Even though our sample municipality authorities claimed they provided a sound infrastructure, there were many cases in our experimentation where these resources were used for administration instead of education: we have had to provide local servers, networks and technical support for the implementation of the MCT system.
3.2 The Sample (2009-2010 implementation)

Table I shows the number of participating (treatment and control) public schools, students, and teachers per country. As mentioned before, districts were selected by their willingness to participate and fulfillment of basic “entrance” requirements.

<table>
<thead>
<tr>
<th>Country</th>
<th>Treatment (no attrition)</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Schools</td>
<td>Classrooms</td>
</tr>
<tr>
<td>Chile</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Ecuador</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Mexico</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>17</td>
<td>24</td>
</tr>
</tbody>
</table>

In general, the selection of the participating districts was a difficult process. It is obvious that without full support and involvement of the district authorities, implementation was impractical. There were some initially invited districts that were necessary to discard due to their lack of real involvement. Finally, only one district per country participated in the project. All schools within a district were invited to participate, but only a few of them decided to experiment with the MCT system.

For instance, the selected Chilean district had 25 schools and only 17 of them were willing to participate. Of those 17, ten were assigned to treatment and seven were assigned to control. During the implementation process, three of the treatment schools dropped out for different reasons: problems with infrastructure, lack of involvement in training, reluctance toward teaching changes, and lack of support from school authorities.

Due to the training process - conducted locally in each country following the guidelines of a global strategy - most participating teachers were enthusiastic and willing to adopt the new strategies and technology. Some teachers (about 20% of initial participants) didn’t have enough time to complete the training. The later ones constituted drop-outs from the implementation and in some cases the school as a whole could not participate. Attrition schools and teachers were not included in the assessment study.

3.3 Improvement of Math Skills

A large amount of collected data has been extensively analyzed. We present here solely observations from the data collected in Chile. It is important to notice that, in spite of training for changes in the teaching process, the main achieved innovation was that students worked in the labs with the MCT system for about 40% of the time (of math classes). The classroom lectures did not change much, beyond the introduction to the MCT strategies. An analysis of quantitative data (pre and post tests) shows the following:

- Students in treatment and control schools have statistically equivalent pre-test scores.
- Post-test differences between the treatment and control schools indicate a statistical improvement in math scores for those who used the MCT system.
- There is variance in math performance among treatment schools.

The primary student achievement outcome measure used in this study comes from two comprehensive, grade-level pre-algebra tests given to all the students (treatment and control). Both instruments were measured with the Alfa-Cronbach test, giving a reliability of 0.77 for the pre-test and 0.80 for the post-test.

One test was given near the beginning of the implementation. The other was given five months later, after the implementation with the MCT system in the classroom and lab. Both exams consist of 44 multiple choice questions. The math material focuses on pre-algebra concepts, as does the software used by the treatment students.

Our research team compiled exam scores from student level results on every question from both exams. Questions were scored as correct (1), incorrect (0), or left unanswered (0). The total score for each separate exam was the sum of correct responses, with no additional penalty for incorrect answers. Unanswered questions were considered incorrect. The final outcome measure used was the gain score from the exams, measured at the student level by subtracting the initial exam score (pre-test) from the final exam score (post-

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Data from Mexico and Ecuador shows similar tendencies as the Chilean data.
A positive gain score means that a student scored higher on the second exam, while a negative gain score denotes a higher score on the initial exam.

Comprehensive statistics on the gain scores are shown in Table II aggregated across treatment and control schools. Across nearly every measure shown in the tables, treatment students have a greater gain score value than control students. In short, a quick glance at Table II supports the notion of a positive overall treatment effect.

### TABLE II

Statistics of the Difference Scores – Treatment & Control (Chile)

<table>
<thead>
<tr>
<th>Sample</th>
<th>All Students</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>788</td>
<td>388</td>
<td>400</td>
</tr>
<tr>
<td>Average</td>
<td>0.28</td>
<td>0.95</td>
<td>-0.37</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.17</td>
<td>4.99</td>
<td>5.27</td>
</tr>
<tr>
<td>Std. Error</td>
<td>0.18</td>
<td>0.25</td>
<td>0.26</td>
</tr>
<tr>
<td>Maximum</td>
<td>19</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Minimum</td>
<td>-22</td>
<td>-15</td>
<td>-22</td>
</tr>
<tr>
<td>Median</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>25th Percentile</td>
<td>-3</td>
<td>-2</td>
<td>-4</td>
</tr>
<tr>
<td>75th Percentile</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

An ANOVA test reveals significant difference in gain scores (Chile: $F(1,786) = 12.99, p = 0.0003$) between the treatment and control populations. The 95% confidence interval from a two-sided t-test is (0.60, 2.03) in Chile. The point estimate of the difference in gain (1.32 in Chile) is approximately 25-30% of the gain score standard deviation across all students within the country, indicating a very substantial improvement. The confidence interval (CI) on the test of whether the sample average from the treatment and control groups are the same does not cover zero at the 95% level.

### TABLE III

Statistics of the Gain Scores by School, Treatment Only (Chile)

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.01</td>
<td>1.29</td>
<td>3.29</td>
<td>0.85</td>
<td>0.37</td>
<td>-0.25</td>
<td>2.23</td>
</tr>
<tr>
<td>Std Deviation</td>
<td>5.09</td>
<td>5.40</td>
<td>5.52</td>
<td>5.27</td>
<td>4.54</td>
<td>5.08</td>
<td>4.18</td>
</tr>
<tr>
<td>Std Error</td>
<td>0.53</td>
<td>0.81</td>
<td>1.20</td>
<td>0.65</td>
<td>0.57</td>
<td>1.04</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Table III shows the gain scores by school (treatment only). There is significant variation even within treatment schools. Some even show negative gain scores, meaning that, on average, students performed better on the pre-test than a post-test of similar material. We hope to explain these large differences in subsequent implementations by considering MCT data and student, teacher, and school characteristics in the evaluation. It is important to notice that when considering students under the mean in the pre-test, they had a larger improvement in the post-test compared with the rest of the class.

With these quantitative results, we believe we have answered the question about the feasibility of building practical cases where, with an innovative technology-supported strategy, we can improve student’s math skills in spite of shortcomings such as lack of resources, low motivation of teachers, math expertise, and initial students’ reluctance towards mathematics.

### 3.4 Motivations and Attitudes of Students and Teachers

As we mentioned in the introductory section, in this study we wanted to determine if we could motivate teachers in LATAM to change their teaching practices and take full advantage of the potential of the CT technology. With respect to the students, we wanted to learn about their motivations and attitudes towards mathematics before and after using the MCT system. Some observations gathered from the Chilean schools’ surveys show that:

- A high percentage (78%) of treatment students was satisfied with their improvement of math performance due to the use of the MCT system.
- After implementation, a high percentage (67%) of treatment students increased their motivation toward learning math.
After implementation, 68% of students felt more certain about their abilities to solve math problems and decreased their perception of math as a very complex discipline.

• 81% of students view the MCT system as a useful tool that substantially helps their learning process.
• 85% of students were satisfied with the usability of the MCT software; 78% of students want to continue using the software tool in their math classes; 88% of students are motivated by the use of computers in their classes.

• 87% of students regarded the teacher as a helpful guide in the learning process using the MCT system.
• 82% of students would like to use the cognitive tutoring system methodology in other subject areas.
• A large percentage (75%) of teachers view the MCT system as a useful and effective mechanism that empowers their teaching process.

• 100% of participating school authorities (principals and area directors) considered the MCT system a useful tool for the teaching and learning of math.
• 100% of participating teachers and authorities would like to continue using the MCT system in the future.

All these qualitative observations from the Chile surveys are very similar to those collected for Ecuador and Mexico.

4 Conclusions and Future Work

We have described an innovative educational implementation based on cognitive tutoring technology. The main objective of the initiative has been the engagement of teachers in a change process that brings improvement of math learning in public schools of LATAM countries, specifically Chile, Ecuador, and Mexico.

Assessment results are encouraging and show that math learning in LATAM can be positively impacted with the use of cognitive tutoring technology. A necessary requirement is the involvement of motivated teachers that change the traditional student-passive classroom methodologies. With support from their teachers, students can get highly motivated to work with the software tools and the math contents. Students are encouraged by the personalized feedback and scaffolding aids provided by the MCT software. They perceive sustained progress in their learning. Teachers feel empowered with a richer teaching environment and use the feedback tools provided by the system as a guide for remedial actions.

According to our surveys and interviews, all drop-outs (30%) were due to problems with infrastructure, lack of involvement in training, reluctance toward teaching changes, and lack of support from school authorities. Despite the sense that change was difficult for the teachers and administration, the fact that 100% of non-drop-out teachers and authorities want to continue using the MCT system in the future is an encouraging result that shows motivation and willingness to change once the value of the new technology is established.

The MCT system shows promising results. Currently, an implementation initiative is underway in 30 public schools of Chile, in urban and rural settings.

5 References


