Building a Robust Language-Infused STEM Education Programs in the Dominican Republic to Advance Engineering Education
A Complex Systems-Based Approach

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Introduction

MACILE, which stands for Mathematics, Science, Engineering, and Language, in Spanish, is a Complex Systems Optimization Lab (COSOLA) program instituted in 2007 to help advance engineering, technology, and science education in the Dominican Republic (DR). MACILE is a research-based program. Two core objectives of MACILE are: (1) design solutions to optimally increase access to robust language-infused STEM (science, technology, engineering, and mathematics) learning environments and quality MACILE resources; and (2) nurture talented young people from less privileged backgrounds and motivate them to excel in the STEM and language education. We hope these students will then rise to the highest educational standards, pursue studies and careers in mathematics, science, and engineering fields, and make a difference in the world by creating opportunities to further advancement of science and technology education in their communities and the country to promote educational and economic development.

MACILE is a collaborative effort. We have been developing the curricula in collaboration with faculty and students from the US. Its main sponsor is a US private corporation. However, the collaborative network of MACILE also includes Dominican schools, teachers, community leaders, and parents. The Spanish language program has been developed by Dr. Rosario de Swanson, Assistant Professor of Spanish and Literature at Marlborough College.

[Includes a brief about the teacher and scholarships programs…]

MACILE is currently a summer program. It targets directly two groups: talented students in the top 20% of the class and teachers interested in improving their processes and become master teachers. We piloted the Summer Academy in 2007 and 2008. Below, we review the observations and results.

The development of MACILE follows three phases, which we summarized as exploration, design refinement, and expansion. In this work, we review the work trajectory, accomplishments, and results from 2007 through 2008, following a descriptive approach.

Students Model Development

MACILE's emphasis on continuous improvement has led to a rapidly maturing student-centered learning system that is producing astoundingly encouraging results.

Summer Academy 2007 and 2008

The initial 2007 Summer Academy lasted for three weeks and included mathematics only. Out of 64 recommended students, 47 attended regularly and completed the program. Their average attendance was 93%. The schedule was from 8:00 AM to 12:00 PM, Monday through Friday, and a healthy breakfast snack was provided. Students were divided into two groups and received two hours of math instruction daily as well as tutoring. A college professor from the United States taught the classes assisted by a local teacher.

Students entered the program with lower than expected mathematics and literacy skills, an unexpected constraint. Nevertheless, many showed great enthusiasm and a remarkable disposition toward the work. They attempted to complete all of the assignments and observed good attendance. Some showed remarkable improvement, organizing themselves into highly inquisitive and hard-working teams. The remaining fell into two broad groups: one group observed good attendance and behavior, but rarely attempted to work on problems they did not understand. They did not ask for help but would accept it when offered. The second group had the lowest math scores and was disruptive. Few could organize the digits

of a sum correctly, and their work, in general, was incomprehensible. These students were less likely to arrive on time and often did not attend. Some dropped out; others were dismissed due to their disruptive behavior.

In light of these observations and research conducted on conditions of schools and families, we adjusted the 2008 Summer Academy. We extended the duration to five weeks and redesigned the curricula to include math, engineering technology, Spanish literacy, and activities such as chess, puzzles, field trips, and guest speakers. We aligned the admission process more closely with the program intention, admitting thirty-five out of 80 students recommended. All admitted students completed the program. (MACILE targets talented students in the top 20% of their class.) We extended the school day from 8:00 AM to 4:00 PM and provided the students with a healthy lunch as well as breakfast. There were a required student orientation and a meeting with the parents. At the conclusion, we administered a math test, and an evaluation questionnaire to gauge the student's mathematical and linguistic progress.

The curricula were developed by college professors, conforming to MACILE's learning philosophy emphasizing critical thinking. The goal was to have friendly and respectful classroom atmospheres where students engage in-class discussions actively and collaborate with peers. A college professor from the US assisted by three Dominican teachers managed the implementation of the curricula. The Dominican teachers received one week of training in the math and Spanish curricula before the beginning of the program.

Despite difficulties with the facilities, students responded exceptionally well to the challenge and rigor of the program. On-time attendance was excellent (98%), and they showed improvement in reading, math, writing, and teamwork. Classroom behavior and etiquette also improved; over time, students learned to listen to each other and to speak calmly. They also bonded as friends, providing remarks at the end of the session, such as:

"*I learned many examples of good behavior, capitalization…"*

"I learned a lot about bridges, solar energy, mathematics, and other things. I also learned that I should not speak with a loud voice and not to disturb others. I also learned that working on a team is extremely important to achieve my goals."

"I learned that I should ask questions when in doubt. If I remain silent, I will never learn what I need to learn. I also learned some mathematics and Spanish. I did not know how to write an essay. I used to make a textual copy of the material."

"This summer, I learned to read better, how to express my thoughts, and how to analyze problems…"

Teacher Development Model

Teachers are the core component of robust learning environments. The teacher-student relationships in the classroom affect learning and the disposition the student may develop toward learning. The ways the curricula are implemented in the classroom, student relations, and other classroom dynamics can motivate or discourage learning. Observations of classroom dynamics in public and private schools in the region of focus of MACILE in DR brought to sharper focus very concerning teacher-students and student to student relation patterns; there were visible signs of conflicts. Teachers were not comfortable with the material and taught by the textbook. They discouraged reading and questioning, requiring the students to transcribe contents from the textbooks and memorize. They also showed poor classroom management skills. Students were restless and undisciplined.

The MACILE teacher development program seeks to gain a better understanding of the needs to design more sound solutions.

The program began as a series of exploratory workshops in Spanish and elementary math for 3rd to 6th-grade teachers in 2008. Classes were held for 2-3 hours a day on Monday through Friday for two weeks. Eleven teachers participated.

The results of this 2008 pilot program revealed, however, that teachers required significantly more extensive training. With one exception out of the 11 teachers participating in the workshop, teachers did not have a fluid sense of how to combine numbers, manipulate fractions, select tools to solve problems, or manipulate expressions and equations. They had difficulty solving simple math problems mentally and using paper and pencil. Literary skills were also surprisingly low: teachers had severe difficulties with critical reading and writing.

These weaknesses in teacher skills are likely the best explanation for the limited skill levels of the students. It was evident through these observations that short workshops would be insufficient to address these deficiencies. Thus the idea of a year-round Teacher Development Institute was contemplated. The program will be extended in 2009 to help more teachers. We will

offer full-time two and three-week-long math and Spanish training workshops. The results will help us to elaborate a more robust strategy.

Collaboration

Collaboration is integral to the MACILE education model. Collaborative efforts on the part of faculty from the United States have contributed to improving the model. Dr. Rosario Swanson, Assistant Professor of Spanish and Literature at Marlboro College, serves as Director of the MACILE Spanish Language Program and has developed the Spanish curriculum.

Efforts to strengthen collaboration with U.S. faculty and students to advance the development of the MACILE model of education continue to progress remarkably well. In addition to the collaboration with Dr. Swanson, COSOLA has also established a collaborative relationship with the Technology and Engineering Education (TEE) program at Brigham Young University (BYU). Members of the faculty will visit summer 2009 to conduct a brief exploratory program. They will work with Dominican teachers and students and will observe the functioning of the MACILE Summer Academy. Their observations, together with other results, will inform the TEE faculty as they organize a study abroad program to assist COSOLA with the development and implementation of K-12 engineering and technology education curricula for Dominican teachers and students. A group of TEE faculty and students will return Summer 2010 to implement the engineering and technology curriculum.

However, the most significant collaboration for the success of MACILE is the assistance from Dominican teachers, schools, parents, and community leaders. Their support has been remarkable.

Scholarships

The main goal of the MACILE pre-college scholarship program is to encourage academic excellence. The program increases opportunities for qualified students to attend the best private and public schools in the province. In addition to financial assistance, the program provides the students with tutoring and academic advisement.

MACILE scholarships program is strictly merit-based. Grade 7-12 students who have participated in the MACILE summer program are eligible. It began in 2008 with five recipients. We expect it to grow each year. The value of each scholarship varies from 125 to 600 US dollars per year. We expect to be able to offer 40-50 pre-college scholarships per year by 2012 and an equal or higher number each subsequent year.

Environmental constraints: overivew

It is generally accepted - widely researched - in the education literature, that the environments at schools, homes, and communities are core factors in fostering learning and understanding. We have researched and observed conditions of these environments in the region of focus of MACILE for almost three years. We spoke with teachers, students, and community leaders; we interviewed government officers, visited private and public schools, conducted a survey, and reviewed relevant reports and other literature to gage pertinent information about characteristics of the environments and how they might be constraints to learning. Following, we summarize some of the observations and findings.

Demographic

MACILE operates in the region of Itabo - San Gregorio de Nigua (Ytabo) in the province of San Cristòbal, which is approximately 23 kilometers (13 miles) southwest of San Domingo. The region includes six towns with an estimated student population of 11,800 (from open records). The median monthly income is less than US$150. On average, parents have completed through the 5th level of primary school (Survey, 2007). Although the precise figures for the region are no well known, but using our data and official reports, we estimated that less than 70% of the school-age student population complete 8th grade, and less than 60% of those continue to high school.

Education decisions and job opportunity

Young people and their families value education. In general, their decisions about education are job-centered due in part to financial limitations, but also because of limited horizons, weak academic capacity, and the reality that in the DR, a college education does not guarantee a better job. College graduates from less-privileged backgrounds often have difficulties finding excellent job opportunities.

"Our conditions do not change most after going to universities. We remain operators afterward" (words of the college student association's president in a meeting

held in 2007 with members of the association form Itabo and San Gregorio de Nigua.)

In addition to inadequate skills and carrier choices, poor command of Spanish and no knowledge of English are also limitations for professional advancement. Ultimately, career choices have a lot to do with low math, science, and language skills, which are essential in order to successfully pursue studies and careers in engineering, science, math, and technology fields in which better job prospects are more generally available. Another difficulty has to do with access. In the DR, young people from less advantaged backgrounds have no access or limited access to excellent job opportunities where they could grow professionally, improve their family lives, and help advance the next generations. Only the best-educated with broad horizons and connections, generally the wealthy and members of the ruling political class, gain access to excellent professional development opportunities.

Since science education is generally poor in schools, students also have had very little exposure to subjects like chemistry, biology, and physics beyond the very basic concepts. Among the students accepted to the MACILE Summer Academy, none have expressed interest in studying science. Although many have indicated an interest in engineering, their understanding of engineering is rudimentary, limited to better-known areas of study in engineering. The most common careers in engineering selected are system engineering and industrial engineering. Other than medicine, careers in science are rarely studied; thus, there are very few people able to teach science or pursue professional careers in science.

Although all students applying to the MACILE Summer Academy claim to like mathematics, none expressed interest in studying math in college. Furthermore, schools suffer from a lack of well-prepared and inspiring math teachers.

n practice, most students choose a career in business administration, marketing, law, and education instead of science, technology, and some engineering fields. These are saturated fields with few job opportunities, even for the better connected. Thus the phenomenon; many, the most fortunate, remain operators after spending many years and much money to graduate from college. In reality, a significant number of college graduates in Itabo and San Gregorio de Nigua remain unemployed or underemployed for years; many never gain a job in their field of study.

Lack of adequate school environments and learning resources

Ytabo's public K-12 schools suffer from the same limitations of most Dominican public and private schools. Facilities are inadequate. They are in disrepair, overcrowded, and lack safe drinking water and appropriate sanitation. There are no libraries or science laboratories. Schools lack the necessary supplies. Electricity is rarely available, and classrooms lack proper lighting. Textbooks are not engaging; teachers and students have no Internet access in the schools.

Lack of prepared teachers and poor teaching conditions

Teachers work multiple four-hour shifts per day, often at different schools, and teach four or more different courses each shift. They have little rest between shifts and work in crowded classrooms. The student-teacher ratio is high, often over 45:1. Teachers have no place to work or rest at school and get no break between courses. These working conditions and personal responsibilities leave little time available for class preparation or to provide individual attention to the students. Teachers are permanently exhausted and discouraged.

Teaching conditions combined with teacher preparation presents a discouraging prospect for the students. Although most teachers have proper educational credentials, the results from the evaluations and extensive classroom observations show serious content and pedagogical skills limitations in critical areas like mathematics, Spanish, and science. Problem-solving, manipulation of fractions, mathematical reasoning, the combination of numbers, critical and analytical reading and writing, and fluid understanding of basic science concepts are areas requiring considerable attention. Other areas where teachers show significant limitations are the development of creative, active curricula from sources and the implementation of new curricula or strategies that move students away from memorization and improve the internalization of concepts. Only a relatively small proportion of teachers show interest in improving their practices. However, the results from classroom observations and evaluations indicate that most teachers in the region require long-term training in all critical areas and excellent support (i.e., resources and mentoring) to improve their practices. Classrooms are generally chaotic; teachers have poor handling of disruptions. It is right to say that poor classroom management, combined with boredom, is likely the main reason for the student's chaotic behavior in the classrooms [3].

Parental involvement and socio-economic ills

Parents want their children educated, but traditionally their involvement in their education, and the schools have been minimal. They register the students, purchase

uniforms and materials, and send them to school. Low-level education of the parents is a factor for the limited involvement, but perhaps the most significant factors are culture or tradition, and beliefs. There is, in fact, no tradition of parental involvement in the children's education beyond the essential requirements in the Dominican culture, particularly in low income and rural communities. Most parents believe that only teachers are qualified to educate the children, and they are mindful of their lack of skills. In addition to limited parental involvement, rapidly growing socio-economic ills (i.e., high unemployment, crime, drugs, alcoholism, and deceases), a large number of families headed by the mothers with little or no support from the fathers, the high incident of abuses, and other ills affecting the communities together with noise pollution around the schools and homes are other important factors affecting learning (Community Evaluation Survey, 2007).

Lack of institutional standards and low investment in education

Contrary to the United States, where the standard infrastructures for mathematics and science have existed for many decades, and significant resources are devoted annually to develop more advanced STEM curricula, Dominican Republic does not have professional organizations or academic institutions involved in the advancement of STEM standards and curricula. Works developed by the Secretariat of Education are still tentative. Far-reaching educational reforms adopted since the 1980s contain no clear standards that reflect the country's needs and expectations in K-12 mathematics, science, technology, and engineering education. The country is still struggling to define a science and technology vision. Its budget for technological and scientific research and development is dismal, as is the budget for educational research in general. Indeed, the overall education budget in the DR has never been higher than 2.7% of GDP in any period [OECD, 2008].

Lack of educational access

Like all public and private (except for the elite) schools in the DR, schools in Ytabo operate in 2-3 short shifts per day to accommodate high demand. Combined with frequent disruptions to the processes (i.e., absenteeism, tardiness, poor class management) and lack of alternative or informal educational opportunities such as public libraries and after school programs, the multi-shift scheme limits access to education to all children. Furthermore, considering the conditions explained above, access to challenging and stimulating learning environments in Ytabo is lacking. Most reports on the state of the Dominican public education indicate that the far-reaching reforms implemented since the 80s have failed to improve access to quality education [OECD, 2008]. Our observations show that in the DR, such access is reserved for the privileged few who can afford the high tuition and fees charged by the elite private K-12 schools. Dominican public K-12 schools place at the bottom of the quality scale in international comparisons.

This lack of access to stimulating and challenging learning processes is not only a barrier to post-secondary advancements in STEM education but a significant constraint to innovations in science and engineering.

Conclusions

The imperative to make substantial continuous advancements in STEM education as a necessary condition for sustainable economic development in the 21st century is both well documented and transparent. Equally clear and significantly more imposing, however, are the complex challenges inherent in the task of making such advances in underprivileged communities, where in many cases in most countries, the vast wealth of human potential lies.

With its novel research-driven system-based approach, MACILE expects to meet these challenges with great success in one area of the Dominican Republic. MACILE's results have been encouraging, and the dynamic growth and improvement of its model is a testament to its strength and robustness. Through our optimization research and process-oriented method, we at COSOLA believe this model can be beneficial to any community in the DR or the US.

he power of the model lies in the fact that the rate of improvement increases over time. As more students gain access to quality education and more teachers receive the required training, education itself improves. Quality of life improves. The knowledge bases of our communities improve. Over time, the pipeline of STEM innovators would significantly expand.

Put simply; we make an investment in our future when MACILE methods are applied. It is an investment with astoundingly high returns. It is, most importantly, an investment that we cannot afford not to make.

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