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The Development, Implementation, and Evaluation of Teaching Engineering Curriculum to Dominican Republic Junior High and High School Students

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Abstract
Over the past several years, a teacher education program in a university in the Western United States has worked in collaboration with a non-profit organization in the Dominican Republic to develop, implement, and evaluate engineering and technology curriculum for Dominican junior high and high school students. This paper will present a summary of the curriculum development process, including challenges and successes of developing and implementing curriculum in a new culture and in a different language. Additionally, a summary of the development of the educational program in the Dominican Republic, including organization of content, selection and admission procedures and the general goals of the program will be presented. Finally, data based on a pre post survey instrument evaluating students' engineering self-efficacy and understanding and interest in engineering content and concepts, future educational and career opportunities, as well as satisfaction of the program will be presented. Additional data regarding the tracking of those Dominican students who have graduated from the program will also be shared to highlight the potential benefits of building a similar program.
General findings include that Dominican students participating in the program had better concepts of and definitions of engineering to include terms such as creativity, innovation and design and that engineering was closely associated mathematics, science and technology. In regard to interest and future employment preferences, pre post data indicated a major positive shift in students interest in engineering, science and technology subjects with a decrease in math and language related subjects. Finally, data collected from students that have completed the three-year program indicate that a majority of these students are majoring in engineering and technology or have completed technical courses at the post-secondary level.

Introduction

This paper contains a report of the collaborative effort between Complex Systems Optimization Lab (COSOLA) and the Brigham Young University (BYU) Technology and Engineering Education (TEE) Program to design a science and technology program to improve Dominican student academic knowledge and skills.

In 2007, COSOLA instituted the Matemáticas, Ciencias, Ingeniería y Lenguaje or Mathematics, Sciences, Engineering, and Language (MACILE) education program to help advance engineering and science education in less advantaged communities in the Dominican Republic (DR) (Shumway et al., 2010). The two core objectives of MACILE are: (1) to develop solutions to optimally increase access to challenging and stimulating learning environments and quality MACILE resources; and (2) to nurture talented young people from less privileged backgrounds. It is hoped that 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 advance science and technology in their countries and communities and to promote sustainable development.

This collaboration initiated in 2009, following a request from the Director of COSOLA. In the summer of 2009, two members of the faculty of TEE, Dr. Ron Terry and Dr. Steve Shumway, visited the DR and spent three days training the teachers and observing the conditions. They presented several classes in technology and engineering to teachers and students. Despite language limitations, their work was enthusiastically received (Shumway et al., 2010).

TEE students and faculty from Brigham Young University returned summer 2010 to the Dominican Republic to continue their work with the MACILE group. This collaboration took the form of an official study abroad program where students developed curriculum, conducted research, taught, and received credit for participation. Eight BYU students and 3 faculty members participated in the program. The students spent five weeks during the summer of 2010 in the Dominican Republic teaching 6th -12th grade students. Content areas included: energy; chemistry; bridges; rocketry; and robotics. The DR students were divided in to four different class groups: 6th-7th grade; 8th grade; 9th-10th grade; and 10th-12th grade. The collaboration continued in 2012 and 2014. Twelve BYU students and three faulty participated in 2012. In 2014, sixteen students and one faculty participated; they spent five weeks each summer in the Dominican Republic teaching 6^{th} – 12^{th} grade students, in 2012, and 5^{th} – 12 grade students, in 2014. Content areas included: simple machines and structures, power and energy, engineering design and robotics, IT communications, agricultural and medical technology, working with others and oneself (Wright et al., 2011).

Under the supervision of three BYU faculty members, the university students developed the curriculum during spring term and then presented the material during summer term. The data presented in this paper is based on a three-year implementation of the curriculum. The data results from a pre post survey instrument evaluating student understanding and interest in engineering content, concepts, engineering self-efficacy, and future educational and career opportunities, as well as satisfaction of the program are presented. Additional data regarding the tracking of those Dominican students who graduated from the program will also be shared to highlight the potential benefits of building a similar program. Although this data is specific to the Dominican Republic, the findings can inform similar efforts in other third world counties, and can also be used for engineering education curriculum development in first world countries.

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Curriculum Development

Overview. From the university perspective, the primary purposes for initiating a study abroad opportunity for the BYU students was to provide pre-service teachers an opportunity to engage in an authentic curriculum development opportunity, develop their teaching and classroom management skills, and to allow students to engage and learn about another culture. The purpose of this section is to describe the curriculum development process.

As students progress through the teacher education program at the university, they take courses in engineering and technology content, as well as general education and teacher education courses. In their first semester in the major, students have a teacher exploration course where they visit local schools, observe classrooms, and teach some basic lessons. A teaching methods class, a practicum experience, and finally the student teaching experience follow this class. In the practicum, the university students are introduced to a curriculum development process called "Backwards Design" (Mitcham, 1994, Wiggins & McTighe, 1998). The main principles of this process call for curriculum developers to first determine what students should know and be able to do at the completion of a unit. The second stage is to determine acceptable evidence or the ability to assess whether students have learned or are able to do the items identified in the first stage. With the first two stages completed, curriculum developers can then effectively engage in the third stage, which is to develop learning experiences and instruction.

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MACILE: Curriculum Development. A total of 35 BYU students were selected to participate in the program. These were from the Technology and Engineering Education program, other engineering programs, and from other BYU programs, including Spanish and education. Each year, after the university students were identified, one of the first things that needed to be completed was to determine what units of instruction were going to be taught during the summer study abroad. From discussions with MACILE and evaluations from prior years, BYU faculty and students knew that they wanted the Dominican students to have opportunities to learn technology and engineering content. However, with four classes being taught at various grade levels, the faculty and students had to decide what specific content should be taught, and to which grade level.

Each year, a representative from MACILE, visited with the BYU faculty and students to engage in the curriculum development process. A key item to emerge from these sections was the need for Dominican students to learn about and be able to engage in the engineering design cycle. Another item deemed important was for the Dominican students to learn what engineers and technologists do, the various types of engineers and technologists that exist, the types of problems they solve, and the impact they can have on society, especially the Dominican society. Additionally, it was considered strategic to lay out a multiple year curriculum plan for the four groups of students to ensure that students participating in MACILE for several years had the opportunity to experience a broad range of topics and an engineering and technology curriculum adjusted to different level of challenges. On average, 54% of Dominican students participating in the MACILE Summer Academy attend for two or more years. Thus, some students may be in the same group for two consecutive years. A challenge for the design process was to complete a two-year plan for each group.

As explained in Wright et al. (2011), the first year, the BYU students and faculty identified and adopted the Boston Museum of Science's *Engineering is Elementary* (EIE) curriculum's engineering design cycle as the model to guide the curriculum development. Additionally, because the units from the EIE curriculum represented a wide variety of engineering content, these units were purchased and used to teach several of the units to the elementary and lower middle school students. The curricula for the high school students included a robotics unit and activities related to rocketry, energy, water filtration, biomedical engineering, and environmental design. MACILE identified the general content for these components

Each year, once the feedback and requirements were evaluated and the basic content identified, the university students continued with the curriculum development process. This process was completed during the seven week spring term prior to the summer study abroad. The students were put into four, multiple-student teams to develop curriculum for the identified classes. As explained above, for the younger grades, units from the EIE curriculum were used. Since these units already included identified objectives, assessments, and instructional activities, the main focus that year was to translate the units into Spanish and then identify how to obtain the materials needed in the Dominican Republic. In addition to the EIE curriculum, the BYU students teaching these younger classes also identified several new units including an invention and innovation unit and developed appropriate curriculum using the backwards design process.

The university students teaching the robotics class in summer 2010 used the backwards design process to develop robotics curriculum based upon the Lego© NXT system. The NXT was used because the university students were familiar with this system and because MACILE had previously purchased several NXT units. For the rocketry, energy, and water filtration class, university students developed a unit in solar energy (passive and photovoltaic) as it was deemed to be a unit with direct application to the Dominican Republic. In addition, units on power and energy concepts related to simple machines and rocketry were also developed. In addition, the engineering design cycle as well as the identification of the types of engineers and related engineering activities became a common theme for each of the developed units.

In 2012, after evaluation of feedback, requirements, and future goals, under the supervision of the faculty, the students designed a multi-year and multi-level TEE curriculum plan for MACILE that included five main components: simple machines and structures, power and energy, engineering design and robotics, IT and communications, agricultural and medical technology, working with others and learning about oneself. Each component included a series of activities and challenges specifically developed to meet the requirements and needs of the program and the Dominican students. The activities were group-specific adjusted to the various levels. They included elements from the Boston Museum of Science, Carnegie Mellon and Tufts LEGO NXT curricula, LEGO Education, and ideas from accepted best-practices in K-12 engineering and technology education curricula. The engineering design process (EDP) is the theme throughout all the curriculum projects.

The curriculum development process in 2014 focused on the review and improvement of designed activities, design of new activities, and advancing translations of the units into Spanish. As in prior years, the students were broken up into four different class groups: $5^{th} – 6^{th}$, $7^{th} – 8^{th}$, $9^{th} – 10^{th}$, and $11^{th} – 12^{th}$. They conducted research, reviewed feedback, consulted with representative from MACILE, interacted with faculty, and selected and ordered materials to complete the process. In addition, they traveled to the DR and taught Dominican students for five weeks.

Challenges and Successes. One of the most difficult challenges related to the curriculum development effort the first year was correctly identifying what the Dominican students should specifically know and be able to do (learning objectives) after having participated in each of the units of instruction. General objectives were identified prior to curriculum development; however, as the process of developing the assessments and instructional activities progressed (stage two and three of the backwards design process), it was necessary to consider more specific objectives identified during the initial planning. The university students had to use their best judgment to integrate these objectives and to identify other specific learning objectives, but without knowing the Dominican students and their prior educational experiences and levels of understanding, despite best efforts to include prior experiences, many of the objectives had to be modified during the actual teaching process.

Another challenge was translation of materials. Some of the university students had significant experience speaking Spanish, but most of them had limited Spanish-speaking abilities. Even though some of the university students were fluent in speaking Spanish, translating the lessons, especially the technical terms, proved to be difficult. To avoid potential confusion, the university students needed to send their translated lessons to MACILE representatives for clarification, or submit their English lessons to MACILE for translation. While the teachers and administrators from MACILE were ready and willing to help with these translations, the university students often did not have time to complete the translations and/or failed to submit their English lessons late —which resulted in a lot of the translation work being completed after arriving in the Dominican Republic. Each year, students involved in the study abroad effort tended to greatly underestimate the amount of time needed to translate the curricular units and the difficulties of using improper translations.

Another challenge was teaching in the foreign language and adjusting to classroom conditions (ex., inconsistent power source, missing materials, Dominican student educational experience, work habits, and preconceived notions) without significant modification of lesson plans. Working conditions are considerably different in the DR. The university students had to be prepared to work without power and in some instances work with limited materials. They also had to account for the communication barriers and possible meaning loss during translation. Some of the university students with limited Spanish and had to rely on students with no technical or educational pedagogy backgrounds who spoke Spanish to communicate with the Dominican Students.

A final challenge during the curriculum development process was identifying teaching supplies and materials, including basic tools that had to be attained in the USA or could easily be obtained in the Dominican Republic. Obviously, for a teaching program of this nature to have sustainability, the majority of the supplies needed to teach the units would need to be readily available in the host country. However, to advance the content taught to the Dominican students to include technology and engineering, many of the materials required MACILE had to order from out of the country. Prior to leaving for the study abroad experience, an effort had to be made to prepare a list of materials readily available in the DR and a list of the materials that needed to be brought with the university students when they arrived in the Dominican Republic. The first year, a challenge arose during the first week when it was discovered that while many of the materials were available in the DR, it was difficult to locate local businesses that sold and had the required items in stock. This resulted in many hours spent locating materials that should have been spent preparing changes to lessons or translating materials.

MACILE Summer Academy; Dominican Republic Students and Program

The collaborative effort with BYU allowed MACILE to offer a full technology and engineering education program. From inception in 2007, MACILE has focused on selecting students at the top 20% of the class that maintain exemplary behavior in their schools and communities and indicate interest in math and science for admission to the academy. The DR students are then evaluated and selected by the MACILE board of directors. When admitted to the Summer Academy, the student becomes a MACILE student and is encouraged to continue progressing in the program until graduation from high school. Students must be recommended for readmission each year. Notwithstanding, due to high satisfaction with the program, retention is very high. The authors believe the satisfaction results from improved academic performance, exposure to new and exciting content taught using a unique (to the DR) methodology.

Findings from previous studies ((Vargas, 2009; Shumway 2010, Wright 2011), reported that the DR students find MACILE curricula challenging and stimulating. In addition, students reported that they enjoy making new friends and being creative and that they feel that they learn a lot in the program and that the MACILE's approach instills in them the desire to learn. Parents want their children to attend MACILE. As a result of the recognition and high satisfaction with the program, demand for admission has exceeded capacity each year. On average, 54% of the students attend for 3 or more years, limiting the amount of spaces available for new students. MACILE admits about 46% of new applicants.

In 2014, as part of the effort to engage talented children in engineering and technology earlier, MACILE began admitting students that have completed grade 5^{th}. The program received 109 new applications. The majority of new applicants, 74%, have completed grades 5^{th} through 7^{th} and ranged on age from 9 to 16. The program admitted 82 students, 30.4% current and 69.6% new. That is, 52% of new applicants were admitted this year and 65% of them have completed grades 5^{th} through 7^{th}. The percentage of students returning dropped in 2014. The program admitted only 1 new student in 2013 while 18 students graduated from high school and exited MACILE that year.

These students came from 16 public and private schools in the San Cristóbal province, including the schools in the Itabo-San Gregorio de Nigua (Ytabo) region where the program operates and four new schools. Since 2007, the number of schools participating in MACILE increased 1100%, going from only 3 in 2007 to a total of 36 by 2014. The growth in demand increased selectivity, as capacity remained constant since 2009. On average, MACILE admits about 46 % of new applicants. The goal is to cap class size at 21 students.

The DR students were divided into four groups by grade and class levels. Groups 1 and 2 included mainly first year students whereas Groups 3 and 4 included mostly current students. By grade levels, Group 1 included students in grades 5 and 6; Group 2, grades 7 and 8; Group 3, grade 9 and 10; and Group 4, grade 11 to 12. Progression in the Spanish and mathematics curricula controlled in great part the allocation of students in Groups 3 and 4. Returning students experience the curricula differently even if the fundamental concepts may be the same. This makes it more difficult to admit new students at these group levels. Class size this year was on target. Over the period since 2009, the average class size per group has been 23, 22, 18, and 16, respectively.

All students come from schools with very traditional Dominican classrooms that emphasize memorization of concepts rather than critical thinking, where active learning or hands-on are not practiced, and where creativity and imagination are often discouraged rather than encouraged. Most students in Groups 1 and 2 had no previous experience in engineering and technology classrooms or classrooms that emphasize active learning, peer assistance and collaboration.

Students attended MACILE from 7:45 AM to 3:30 PM Monday through Friday for 5 weeks, usually from last week in June through first week of August. They received breakfast, lunch and one snack. MACILE summer programs are provided essentially free of charge, with most students paying only for transportation to and from the program. In 2014, for the first time, the program provided transportation assistance to needed students who could not have attended otherwise. The academy was again conducted in the Center Padre Zegrí , a Catholic School, in Nigua, where it moved in 2009.. MACILE will move to its own location in 2016.

In addition to learning about engineering and technology, the DR students received instruction in mathematics and language (Spanish). A project-based chemistry component for students in Group 4 was piloted in summer 2013 and integrated as part of the science curriculum in 2014. The goal is to include a science curriculum at all the levels by 2016.

MACILE's mission is to nurture talented young people from less privileged backgrounds. As a result, the program emphasizes continued improvement, with a focus on expanding and improving outreach to all less privileged students in relative close proximity to the school. Since 2012 new initiatives have been adopted to expand and improve services, for example: (1) Engaging younger students in science, engineering and technology. In 2014, the program admitted students that completed grade 5^{th}. The plan is to admit students in grade 4^{th} through 10^{th} in 2016. (2) Providing preparatory support to students receiving MACILE scholarships to help them prepare better for success at more demanding Dominican high schools and colleges. MACILE also provides academic advising and special courses to strengthen core skill sets and abilities, improve reading and reasoning, increase English skills, and introduce basic computer programmingg. (3) Introducing a college scholarship program to help students pursue careers and studies in STEM fields. The goal of the scholarship program is to encourage talented students to aspire to attend top Dominican colleges and enter US colleges and universities to receive additional technical training. Six students have been awarded four-year college scholarships since 2012. The pre-college scholarship program began in 2008 and 28 students have attended high school with MACILE scholarships since then. This program increases access to better high school education opportunities for talented students from Ytabo and encourages high school completion. (4) Opening a library-special classroom with extensive media resources and capacity for distance instructions. (5) Assisting MACILE students that have completed high school with internship and apprentice placements; 15 students have been placed; five have gained full employment. (6) Introducing transportation assistance to and from the school for those students with travel restrictions.

Understanding of the nature of engineering and technology

The following section of this paper focuses on the technology and engineering education (TEE) component of the program. Three main goals for the curricula are: (1) to immerse learners in challenging and stimulating classrooms where reliance in memorization, as normally done in the Dominican classrooms, is discouraged and the focus is instead on critical thinking, creativity, discovering engineering and technology, and building collaborative (and leadership) skills. (2) Motivate the learners' curiosity and instill in the young minds interest for learning. As previously stated, the Dominican classrooms consistently discourage curiosity, creativity, and inquiry. (3) Improve understanding of the nature of science, engineering, and technology to widen the horizons, motivate students to pursue studies in STEM fields, and contribute to develop better-educated citizens.

Below pre post results are reviewed to assess student understanding and interest in engineering content, concepts, engineering self-efficacy, and future educational and career opportunities, as well as satisfaction of the program. Preliminary results regarding the tracking of students who have graduated from the program are also shared to highlight the potential benefits of building a similar program. The findings, although specific to MACILE and the Dominican Republic, can inform similar efforts in other third world counties, and can also be used for engineering education curriculum development in first world countries.

An important goal of the curriculum was to expand the DR students' understanding of the nature engineering and technology. Although recognizing that questions such as "what is technology?" and "what is engineering?" have long been debated by philosophers of engineering and technology, where there are a variety of answers (Mitcham, 1994; Petroski, 2000; Broome, 2006), we asked these questions to gain understanding of the students' perceptions of these topics, in an effort to establish a baseline from which we could teach and scaffold from, in an effort to help broaden the DR students' understanding about technology and engineering. The pre and post assessments included three questions specific to their perception of technology and engineering: "what is engineering?" "What do engineers do?" And "what is technology? (list 10 examples)" The pre-test was administered only to students new to the program while the post-test was administered to all students. The reason the pre test was only administered to the new students is because the repeating MACILE students have had exposure to the TEE curriculum for one or more years and their views of engineering and technology have likely changed in some ways over the periods.

In a prior work (Shumway et al., 2011) contrasted post-test responses to similar questions to analyze the DR student mental models for depth, complexity, or sophistication of thinking. The groups were labeled: Group 1, Group 2, Group3, and Group4. The results showed that students in Groups 3 and 4 (high school students) had more sophisticated and complex mental models about the general concepts of engineering, technology, and things done by engineers than students in Group 1 (grades 6^{th} and 7^{th}). In this work, we do not make distinction among the different groups. We evaluate the depth, complexity, and sophistication of thinking of the students globally. The goal is to assess changes in their views of engineering and technology and whether the TEE curriculum might have influenced these changes over the five weeks of instructions.

What is engineering? A significant number of students (37%) did not answer this question in the pre-test. Of those responding, 56% employed phrases like "construction of houses, building, or bridges" to define engineering, and 39% of them associated engineering with a person or profession, defining engineering as a field of study - to study at university - or the person that builds building, bridges, and machines. Alternatively, 33% considered engineering a science; an entity in itself, or the capacity to do things. Only 6% related engineering with technology while 11% included terms like administration and business to define engineering. Three students, however, associated engineering with creativity and the capacity to transform human lives: (1) “Engineering is a form of cultivating the engineer; cultivating the creativity that the person has;” (2) “Engineering is the process through which an object is created from another object;” (3) “Engineering is an ample science with many branches that encompasses everything around us and create useful things for today and the future.” These views are remarkable for youth with no prior exposure to a TEE curriculum.

In the post-test, most students (95%) responded to the questions. The most noticeable difference when comparing these results with the pre-test, is the frequency words or phrases like creativity, innovation, design, knowledge, and improvement appeared in the definitions of engineering. 42% of the students associated engineering with knowledge. The word “creativity” appeared in 33% of the definitions; “imagination” and “design” in 21%; and “improvement” in 26%. The students repeated these words often in class while internalizing the engineering design cycle.

Most definitions (53%) provided in the post-test still included the word “construction,” but this was not only linked to houses, building and bridges. “Construction” was linked to robots, structures, machine, autos, motors, airplanes, and others artifacts. Additionally, in most instances “construction” is part of the definition, terms like knowledge, creativity, design, imagination, improvement, and utility are also employed, indicating that the students developed a broader view of engineering over the period of instructions. As explained above, EDC was the theme throughout the TEE curriculum. Imagination, design, creativity, and improvement are integral to EDC as is the notion that engineers solve problems to improve human lives. In the responses, many students viewed the application of knowledge to find solutions to problems and make human lives easier as part of engineering. Some students (26%) considered engineering a profession or discipline, but 26% of them also recognized the existence of many types of engineering. Finally, a few related engineering with advances in medical fields

Another important difference in the definitions provided in the pre and post-tests is the inclusion of terms like mathematics, science, and technology in the definitions of engineering. Whereas no student viewed math and science as relevant to engineering in the pre-test, 7% did in the post-test. Similarly, 15% related technology to engineering in this test and only 6% related technology to engineering in the pre-test. Chart 1 below compares the difference between the students’ definitions of what is engineering. The data suggests that students had a more broad and diverse definition of engineering after participating in the intervention. For example in the pre-test the students reported six common definition themes for engineering, whereas in the post survey students reported nine different definition themes – which also more accurately align with contemporary definitions of engineering.

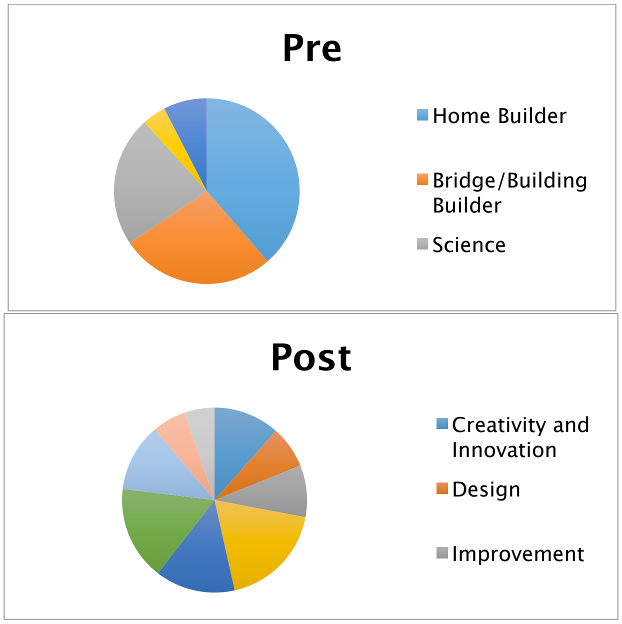


Chart 1: Comparing Pre and Post Student Definition of What is Engineering?

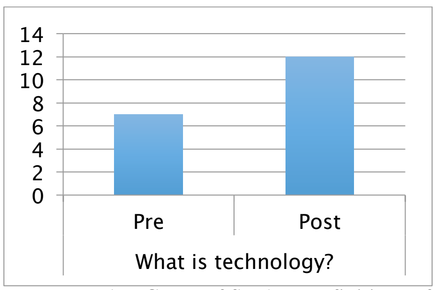
Contrasting the pre and posttest results, we can conclude that the students modified their understanding of engineering over the five weeks of instructions. While diverse, their views showed sophistication and complexity. The mental models became richer and broader by the end of summer.

What does an engineer do? This question was essentially missed in both tests. The few responses (5 in total) defined an engineer from a narrow perspective as "the person that build and repair houses, supervises construction, works with drawing, or administers money". In a prior year evaluation, we found that instruction helped shaped the student's views and that there were difference or evolution in regard to the depth of the mental models between younger and older students after the five weeks of instruction (Shumway et al., 2011). In this work we showed that the youngest students (grade 6^{th} and 7^{th}) overwhelmingly viewed engineers as builders of houses, bridges, and buildings. Very few (< 10%) associate the work of engineers with creativity, planning, or problem solving. In contrast, only 6% of students in grade 10^{th} to 12^{th} considered the work of an engineer as building houses, bridges, and buildings. For this group, an engineer creates, designs, plans, and solves problems to improve the quality of life.

What is technology? The students were more comfortable with this question. Their responses were 79% in the pre-test and 92% in the post-test. In the pre-test, their views were diverse and sophisticated, considering that 65% of the students had only completed 5^{th} through 7^{th} grade. In general, the students provided two related perspectives of technology: (1) Advances and evolution through time of electronic and electric artifacts, and (2) things that we use, mainly electronic and electric apparatus. 53% of the students espoused these views. They considered the advances and evolution in electronic and electric artifacts - computers, cellular phones, tablets, televisions, and cameras - very important for the people. These artifacts were resources necessary for the development of the country. In essence, technology is what advances society and technology is the same as electronic artifacts. In the words of some, technology, namely electronic artifacts, "is one of the most important steps the man has made." On the other hand, 13% of the students still associated technology with electronic and electrical objects, but they also view it as the science that studies the advances in electronic and electrical objects and permit their creation. That is, technology creates and advances artifacts, but it is not the artifacts. This contrast with the definition that technology comes from electricity and is the same as the electronic objects we use like computers and cell phones provided by 15% of the students. Finally, 20% of the students defined technology as "things" we use, which implies a wider view; however, it is not clear what "things" the students are referring to.

From the results of the post-test, it is clear that there was a remarkable shift in the students understanding of technology over the five week period. Only 4% of the students defined technology as electronic and electric artifacts while 78% related technology to knowledge or science, innovation, advances and evolutions that have utility for mankind and contribute to progress. Moreover, 17% considered technology ubiquitous, suggesting "we are surrounded by technology." This shift in views indicates an evolution over the five weeks of instructions.

An evolution in understanding is also noticeable in the examples of technology the students provided in the pre and post-tests. In each case, the students were asked to provide ten examples of technology. In the pre-test, all the students provided examples, but many provided less than ten. Graph 1 shows a comparison of the average student response count. In the pre-test the average number of examples provided was 7, whereas the average was 12 in the posttest. In the post-test, most students (94%) provided ten examples of technology. But, more importantly, the examples provided in the post-test were more diverse. In the pre-test, 100% of all the answers included electronic and electrical artifacts commonly used or known like computer or laptop (84%), cell phone (77%), iPad (41%), television (74%), fan (65%), and refrigerator (63%) as examples; while 36% of the answers included examples of other artifacts. Within these, 32% listed objects like chair, door, clothing, table, and toys as examples; 19% listed machines like auto, airplane, helicopter, and train; and 20% mentioned robot and advances in medicine. In addition, 23% listed Facebook, Twitter, Email, and the Internet as examples of technologies.



Graph 1: Average Number Count of Student Definitions of Technology

In the post test, while many of the answers still included examples of electronic (70%) and electric (49%) artifacts, most (85%) also included examples of other artifacts found commonly in the homes, schools, and most places we go, such as: paper, pencil, table, chair, airplane, auto, window, glass, building, and microscope. In addition, 15% of the answers included examples of ideas, knowledge and procedures as technology such as: software, books, Internet, and heart surgery.

Comparing the pre and post test results, it is clear that the students had average mental models about engineering and technology prior to entering the MACILE classrooms and that these models changed over the five weeks of instructions. After the five weeks of instruction, the models were more sophisticated and complex, reflecting deeper thinking and understanding of engineering and technology. In 2014, the definitions of engineering and technology, and the examples of the latter showed expansion on the students' views. These results are consistent with prior findings. Shumway et al. (2011) showed that over the five weeks of instruction students developed more sophisticated and deeper understanding of engineering and technology.

While how the students actually explained the concepts of engineering and technology may not reflect their full understanding, it is possible to infer that the mental models that emerged from their answers showed how they internalized the concepts; their understanding of engineering and technology. Furthermore, we can argue that these models and how the students form them can play a role not only on how they learn about engineering, science, and technology (NRC, 1999 and 2005) but also in future decisions about studies and careers. We should note that while a very small number of new applicants (< 8%) usually expressed interest in engineering, by the end of the five weeks of instructions, a very significant majority (over 70%) of the students indicated that they liked engineering and will consider studying it. For these students, "engineering" is much more than a field of study. Most (69%) viewed it as a science dedicated to solving problems, creating, and building things to satisfy needs. Moreover, overwhelmingly, these students associated an engineer with creativity, design, planning, and the solution of problems to improve human lives. When they were asked what they would like to do for a career later in life, many answered they would like to work as an engineering. When asked why they want to be engineer, many expressed interest in design and the desire to help their communities.

How they are doing after MACILE?

In this Section, we present a brief analysis of the education and career interests expressed by the Dominican students. We also review preliminary results from a follow-up survey of 46 graduates to provide insights into their actual career choices, contrasting their decisions with prior data. A more extensive study will be needed to draw firm conclusions on the influence of MACILE on the students' educational progress and career choices after graduation from the program. Nonetheless, these results provide insight into the potential benefits of building a program like MACILE and establishing collaboration to advance TEE curriculum in less-advantaged communities.

Student interest: When a student applies for admission to MACILE, he or she completes, a pre-evaluation, including, among others, three questions: (1) what do you expect to receive from MACILE? (2) Why are you interested in math and science? (3) What is your favorite subject? Likewise, at the end of summer academy, the students complete a post- evaluation of their overall experience that summer. They answer a series of questions, including: (1) what did you receive from MACILE? (2) What was your favorite subject or class? (3) What would you like to study in the future?

In general, applicants expected to learn more, to learn new things, and gain more understanding. Almost all claimed they liked math and science and wanted to increase their knowledge of them. On average, 52% of applicants indicated mathematics as their favorite subject, 21% liked natural science; and 20% preferred Spanish or language. Only 5% of the students indicated interest in technology and engineering. By the end of the five weeks of instructions, however, their preferences had changed remarkably. Most students (53%) expressed interest in engineering and technology while only 4% expressed interest in math and 38% was interested in science, and only 5% were interested in language/Spanish as their preferred subject area. It was however interesting to read that 17% of the students wrote in that they were now planning to study medicine. The rest indicated interest in accounting (7%) and other fields, including education. In addition, all the students claimed their expectations about learning were very satisfied.

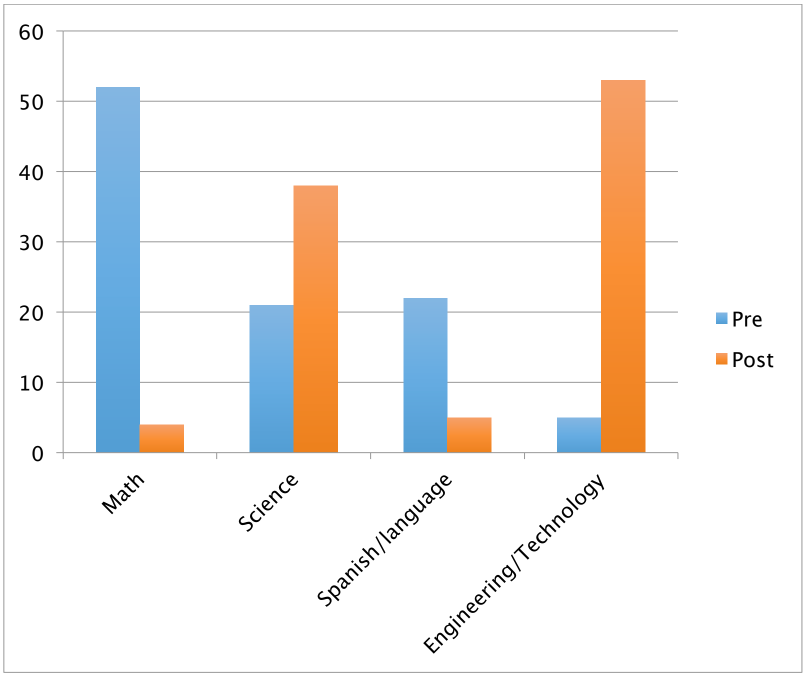


Chart 2: Pre Post Comparison of Student Subject Area Interest

Follow up survey results: MACILE currently has 84 active students, but the program has admitted 391 since 2007. Although we have information about the progress of many of our former students, it is only recently that a systematic effort has been incorporated to follow up on students after leaving the program. The follow-up survey database currently has data about 46 of the former students. The plan is to contact the students periodically and document their progress. Below, we report the results of 46 surveys conducted thus far.

The results showed that 54% of the students are majoring in engineering and technology or have completed technical courses; 12% are majoring in medicine; 7% in education; 15% in accounting & business administration; 2% economics; 5% science; and 5% psychology. In addition, 14% have completed an English immersion program. Furthermore, 41% work full time and attend college part-time (the norm in the DR) while 17% is currently seeking employment. Of those currently employed, 33% work for companies where MACILE helped them secure internships. A number of the students contacted indicated financial limitation and potential employment opportunity as the main reason for selecting their majors, but most said that they were following their passion. All the students surveyed credit MACILE for their progress. They claimed MACILE changed their lives, helping them become "better and more disciplined" students.

Student satisfaction and continuous improvement

Satisfaction with the instructions and MACILE in general remained consistently high each year since the program's inception. Students often used words like "unforgettable," "marvelous," "maximum," "impressive," "unique," "fascinating," and "very good" to describe their experience. On average, 97% will return to the summer academy if granted the opportunity again. They felt that they gained new knowledge, learned a lot about things new to them like engineering and science, made new friends, and developed greater capacity which will help them perform better at schools. Students appreciated the guidance given to them. Above all, they were fascinated with the way they were taught and the kindness of the teachers.

Parents, teachers, and the schools have consistently praised MACILE and have encouraged their children, colleagues, and the schools to participate (Vargas, 2009; Shumway et al., 2010 and 2011). As explained above, in 2014, students came from 16 schools from the province of San Cristóbal province, including public and private schools from Ytabo. Currently all public schools and some private schools in region participate. The most difficult part each year is explaining to unhappy children, parents, and teachers why we were unable to admit more.

Despite their satisfaction, the DR students have still been able to suggest areas for possible improvement. Four common themes identified were: student selection (Shumway et al., 2011), student behavior (2014), food (2012, 2014), and schedule (2014). On average, 21% found the food unacceptable, 13% disapproved the behavior of their peers, and 7% found a full-day of classes and activities difficult. The most telling fact, we feel, is that the students showed appreciation for the vision and mission of the program and disapproved of peers that seemed less interested on learning; they noticed the behavior of their peers.

Conclusions and Future Plans

The collaboration between the TEE department at BYU and MACILE from 2009 through 2014, opened an invaluable opportunity for talented Dominican youth from less privileged backgrounds to gain better understanding of the nature of engineering and technology. They had somewhat sophisticated, but limited mental models about engineering and technology when admitted to MACILE, which evolved over time into sophisticated and complex models as they participated in the summer academy. Concurrently, our data shows on average the DR students improved their math, science, and language skills while learning more about engineering and technology. They also learned about teamwork, problem-solving, peer assistance.

Another very significant part of the collaboration was the opportunity it provided the Dominican students and local teachers to interact with teachers and professors from a United States university and to be immersed for multiple weeks each year in challenging, stimulating, and fun learning environments different from the traditional Dominican classrooms they are accustomed. Without exception, all the Dominican students rated this the most fascinating part of the experience. They used words such as: marvelous, inexplicable, and unique to explain it.

While we cannot affirm that MACILE has motivated the post-secondary education choices the students that participated in the program have made, we can infer from the results that MACILE has played a significant role. The significance of this role needs to be further researched. A goal is to assess the extent to which the program could inspire young people to embrace a lifelong passion for learning STEM (science, technology, engineering, and mathematics). Another goal is to determine how MACILE, overall, is influencing the lives of the students and their families. Looking ahead, our next goal is to extend and improve the TEE curriculum to integrate it as part of the MACILE preparatory academy curricula and for teacher training purposes.

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