The Teaching and Evaluation of Technology and Engineering Concepts to Dominican Junior High and High School Students

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Introduction
A University in the Western United States has collaboratively worked with the Complex Systems Optimization Lab (COSOLA) to develop technology and engineering curriculum for Junior and High school aged students in developing countries. The curriculum has been developed over a two-year period and was recently implemented for the second time in the Dominican Republic. Eleven technology and engineering education (TEE) college students from the United States taught the curriculum to four different grade levels (students were grouped into four courses based on their age: 11–12 year olds, 13–14 year olds, 15–16 year olds, and 17–18 year olds) during a 5-week summer internship program in the Dominican Republic. Various donors, the COSOLA program, and the U.S. University sponsored the program.

This paper will: 1.) Outline and discuss pre and post findings of the DR students from the technology and engineering inventory; 2.) Discuss the cultural implications of teaching technology and engineering in a third world country like the Dominican Republic; and 3.) Outline what was done and learned by the eleven college students and four supporting faculty members while participating in the development and implementation of this course.

Dominican Student Responses to the Technology and Engineering Inventory
An understanding of the Dominican students’ perceptions, attitudes, and definition of technology and engineering was an integral part of this research project. Consequently the researchers used a mixed research methodology consisting of: 1.) A pre/post technology and engineering attitudinal survey, and 2.) Field observations gathered by the eleven college students, and the three professors monitoring the program. Although the methodology seemed appropriate for this study, the analysis of the data proved the methods were influenced by several cultural barriers. For example, during the first data collection effort – the administration of the pre technology and engineering attitudinal survey, there was a misconception with regards to the meaning of a “survey”. From the responses collected in the survey, it is apparent that the survey was interpreted as an exam, where the Dominican students thought they were required to have precise answers, rather than report their personal impressions and interpretations. Consequently many of the students used dictionaries and older siblings or parents to answer the survey.

For example, answers to the question “Define Technology” (Definir la Tecnología) were wide and varied. Many of the student responses (23%) were exact copies of one another, often utilizing dictionary based responses, far exceeding the lexical skill of any of the other student responses recorded on the surveys. Eleven–year-old students wrote definitions such as, “It is the combination of technical knowledge,
organized by scientists so that goods and services might be created that make life easier for humanity.”, while an average 15-year old simply wrote, “It's what man has created in order to make life easier.” These findings are further evidenced by a student who wrote, “I couldn’t find it”, meaning that they were trying to search for a correct answer in a book, and not give one that was a true representation of what they knew or thought. Similar results were obtained in response to the question, “Define Engineering” (Definir la Ingeniería). Definitions such as “engineering is the whole of technical and scientific knowledge that is applied to the creation of structures in either a physical or technical sense,” and, “[Engineering is] the combination of scientific knowledge referring to the best use of natural resources”, both of which were copied throughout 23 of the 78 responses collected. In the post survey, the memorized definitions were no longer present. Although no comparison between pre and post definitions were made due to the significant differences in pre and post definitions, the researchers did notice that the post survey definitions seemed to better represent a more broad and holistic understanding of technology and engineering. For example, students that answered the responses above responded in the post survey, “[technology is] the whole of knowledge and techniques,” and “it is the combination of components and elements that are united to make life easier for us.” Of note is that the trend of copying also disappeared.

Although the data regarding the interpretation and meaning of the survey proved interesting and insightful, but not valid, the survey did reveal other important findings regarding DR student understanding and interest in technology and engineering fields. For example, one of the primary research goals of this study was to understand the change of DR student interest in technology and engineering fields as a result of a course therein. The pre-post survey questions, “Have you ever considered a career in Technology?” (¿Alguna vez ha considerado una carrera en un campo de la tecnología?) and, “Have you ever considered a career in Engineering?” (¿Alguna vez ha considerado una carrera en un campo de ingeniería?) helped the researchers understand this potential attitudinal shift. Data was collected exclusively from surveyed students that stated a clear positive or negative affirmation as to their choice, and the results are shown below in table 1-1. The table shows that student interest in engineering fields increased, whereas interest in technology fields decreased. The researchers believe this result stems from the curriculum taught. The curriculum was heavily based in engineering content, whereas very little technology curriculum was taught. It is believed that the increased interest in the fields of engineering may be due to an increased understanding of the field of engineering.

<table>
<thead>
<tr>
<th>Have you ever considered a career in technology?</th>
<th>Have you ever considered a career in engineering?</th>
<th># of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>69.23%</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>25.64%</td>
</tr>
<tr>
<td>Pre-Instruction</td>
<td>69.23%</td>
<td>78</td>
</tr>
<tr>
<td>Post-Instruction</td>
<td>42.42%</td>
<td>66</td>
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<td></td>
<td>21.79%</td>
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<td></td>
<td>22.73%</td>
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Table 1-1: Careers in Engineering

The curriculum did not teach any information on the subject of technology careers, which could explain their lack of interest in those fields. However, it is also possible that
students in the Dominican Republic are simply not aware of technology career opportunities because of the lack of parents, siblings, friends, and neighbors who work in fields associated to technology (i.e., IT, programming, digital media, and so forth). The researchers believe this is highly likely because of the lack of electricity and computer access in the region where the surveyed students lived. In fact, when the students were asked to name the careers of people that they knew, 46 percent stated that they knew individuals who made their living through work in the industrial sectors of the island (called the Zonas Francas) or as generic laborers, machine operators holding 20.5% of the supplied answers, and teachers and secretaries occupying 18 percent each. Only in 11.54% of responses did the word “engineer” appear (which is likely skewed because the survey primarily asked questions on the subject of engineering, and students would be more likely to think of engineering in this setting), suggesting that only a small portion of students had any prior exposure to the discipline. In addition the word engineering is defined differently than the English definition. In the DR, engineering includes areas such as auto mechanics, machine operators, and fire fighters who are responsible for the fire engine.

Cultural Implications of Teaching Technology and Engineering Concepts to Middle and High School Students in The Dominican Republic.

When teaching students in another culture, and in a language that is non-native to the teachers, there are many cultural implications that need to be considered when developing and teaching the curriculum. Some of the implications can be anticipated and adjusted for before the teaching experience, while other implications do not manifest themselves until engaged in the teaching process. In this section of the paper we discuss anticipated and non-anticipated cultural implications that were experienced by the group, along with some recommendations for mitigating these implications.

Language

The most obvious cultural implication faced by the university student teachers when preparing for this study abroad teaching experience was the barrier of language. Fortunately, several of the student teachers were native Spanish speakers while others had high-levels of Spanish speaking ability from previous experiences in living among Spanish speaking populations. Even with this proficiency in Spanish, it was soon discovered that Dominican Spanish was a little different from Spanish spoken in Mexico, Argentina or New York City (where many of the university students had learned Spanish). As one student commented, “I had a rough time adjusting to the Dominican accent, but as long as the students spoke slowly I could pick up most of what they were saying”. In addition, while a few of the student teachers had previously studied Spanish as part of their high school experience, it was soon discovered that this level of Spanish was not adequate to teach the Dominican students without additional help.

The first strategy to alleviate difficulties related to language barriers was to first partner the student teachers who were fluent in Spanish with those that had limited abilities. In addition, the majority of the student teachers with advanced Spanish speaking abilities were assigned to work with the younger DR students while those with limited Spanish abilities were assigned to the advanced high school class.

This ability-differential approach seemed to work well throughout the experience, especially for those with limited Spanish fluency. In addition, by establishing a culture in
which the student teachers with limited Spanish-speaking abilities and high school DR students were translating for each other, the DR students were able to improve their English while the student teachers ability to speak Spanish improved dramatically. One of these student teachers commented, “The language was not nearly as much of a barrier as I thought it would be. In fact, it almost brought us together more because it was something we could help each other with. Our "Word of the Day" became a great bonding tool because they (the Dominican Students) were able to learn some English, while I better learned better Spanish. The activity made it less scary to them – it was something fun and helpful.”

Image 1: Student teacher with two DR students

Curriculum Development

The curriculum to be taught during the study abroad experience was developed by the university student teachers and supervisors several months prior to, and then throughout the teaching experience. Because language was a known perceived implication, the lessons were first written in English with a practice of using symbolic representation of content as much as possible. The theory was that graphic representations of content such as schematic symbols, drawings, pictures, programming icons, flow charts, mathematic equations and hands on demonstrations were cross-cultural means of communicating and should be incorporated as much as possible. Finally, the lesson plans and other curricular materials were translated into Spanish by those student teachers with Spanish fluency.

During the actual teaching experience, the student teachers found that the use of graphic representations of content helped the teaching and learning process. Concerning this, one of the student teachers commented, “I definitely had to rely on visual representations more than if I were teaching American students.” Another student commented, “I spoke a lot with my hands and used a lot more inflection. I think it helped my normal teaching because I learned to explain things better in more ways than just my words.”

One of the un-anticipated cultural implications faced at the beginning of the teaching experience was that in some cases, the Dominicans use different terminology and common phrases, especially related to technical content, than that of other Spanish
cultures. Given this, some of the curricular materials previously developed and translated by the student teachers caused some confusion for both the student teachers and the Dominican students. Because of these difficulties, the director of MACILE, a native Dominican with a Doctorate in Engineering from the United States, was asked to review the lesson plans before teaching, and was thus able to help translate the lessons into Dominican Spanish that DR students could better understand. Following this procedure helped the lessons flow much easier for both students and teachers. Unfortunately, because of day-by-day changes that were needed, the university student teachers were sometimes re-writing their lesson plans the night before teaching, and the review of lesson plans by a native Dominican was not always possible. In the future, one of the most important features of curriculum development is to have a native speaker that has a good knowledge of the specific content to be taught conduct a review of all curriculum materials.

Interactions

Another implication when bringing students and teachers from two cultures together is some feelings of discomfort, intimidation, or misunderstanding. Essentially, there are cultural barriers that need to be addressed. For example, several of the student teachers discovered that the DR students would tell them that they understood the content, when they really didn’t, rather than risk offending the student teachers. Through experience, it was discovered that the fastest way to overcome these misunderstandings or feelings of being uncomfortable was to immerse the two cultures together. The DR students and student teachers ate lunch together, went on several field trips together, and the DR students taught the student teachers hand-clapping, singing and other games. By the end of the teaching experience the interactions between the two cultures became one of the greatest strengths of the program - rather than a barrier.

Image 2: DR student building a bridge

Classroom Culture and Management

One of the main purposes of the study abroad teaching experience was to teach the DR students STEM-related content that they would not normally receive as part of their educational experience. Given this, the central concept in each of the lessons and classes was to teach the engineering design process. Engineering design is a dynamic
process in which students typically identify a problem and then use an iterative process to imagine, plan, create, test and improve upon their design. From the beginning of the teaching experience, it became apparent that the DR students were not comfortable participating in an iterative design process, especially one that involved group work. These students (like students from many cultures) had been conditioned through previous educational experiences, that there is typically one correct answer, or only one way of doing things; thinking creatively was a new concept for them. One of the student teachers commented on this saying, “The [DR] students did have the adequate knowledge of science and math and were able to quickly understand what we were trying to teach them, but when participating in engineering design, they needed to learn to be creative which was sometimes a struggle.”

One of the manifestations of the DR students’ struggle with participating in the design process was observed while watching them design and build solutions to problems. For example, if one group of students was able to develop a successful solution to a design problem, then the other students would abandon there designs and copy exactly the design of the first group. Furthermore, the DR students viewed this as an acceptable and efficient approach. To address this issue, the student teachers had to repeatedly emphasize the concept that there are multiple correct solutions for a given problem. By the end of the teaching experience many of the DR students had made significant progress in their design thinking. Notwithstanding, this continues to be a cultural teaching issue that still needs to be addressed in future cross-cultural teaching experiences.

Another teaching implication that was not anticipated was some classroom management issues that were manifested when the DR students were participating in engineering design activities. In order to engage in the engineering design process, the student teachers put the students into small groups and provided for a significant amount of autonomy for the groups to brainstorm and come up with creative solutions. The DR teachers that were observing this process cautioned the student teachers that the DR students were used to a more structured classroom experience. The result was that the classroom work became somewhat chaotic, where DR had a difficult time working in groups, being creative, and moving past the ideation stage of engineering design and into the planning and creating stages. To adjust for this the student teachers had to train the students how to work together, use their autonomy, establish time limits to the ideation stage of the engineering design cycle and force the students to move into planning and creating stages, while also working collaboratively with each group.

Technology/Availability of Materials

Another teaching implication that was anticipated when teaching STEM content in the Dominican Republic was that there would be limited opportunities to use technology when teaching, and that there would be a limited use of electricity in the communities in which the educational experience was located. As one student teacher reported, “Lessons needed to be planned as if there was no power”. To manage this, lessons had to be planned around the use of simple technologies that would still allow for effective teaching of basic technology and engineering concepts. For example, when teaching basic electronic circuits, batteries that are readily available, were used as the power supply, and Christmas tree lights, which were cut into individual bulbs, were used to teach Ohm’s Law and series and parallel circuits. Paper, cardboard, wooden dowels, string, tape and glue are all readily available and can be used to teach concepts from
simple machines to structures, and even rocketry. As one of student teachers stated when asked about curriculum development and finding materials for teaching and learning activities, “Moral of the story, learn to improvise”.

Many basic teaching materials are available in the Dominican Republic, but can only be easily obtained by travelling into the large cities. Since this teaching experience was located outside of the capital city of Santo Domingo, a successful teaching experience necessitated that many of the materials needed to be either a) purchased by locals that are familiar with the available of materials, and how to easily obtain them, b) shipped ahead of time to the teaching location, or c) brought with the student teachers while travelling. If you wait until you arrive in the country to find and purchase materials, a significant amount of time and expense will be needed to purchase even the most basic of supplies. For example, the student teachers had a difficult time finding galvanized nails for electronics activity. They resorted to cutting up a sheet of galvanized roofing to adjust for the unavailability of nails.

What the Pre-Service Teacher’s Learned While Participating in the Implementation of the Curriculum.

Eleven college students participated in the program. These consisted of six Technology and Engineering Education (TEE) majors, two Spanish Education majors, one Mathematics Education major, one Manufacturing Engineering Technology (MET) major, and one English major. Of the eleven students, five spoke good Spanish, four could communicate a little, and two knew no Spanish. The challenge for the faculty, since we were to teach engineering and technology content, was to be able to align students who understood the content with at least one proficient Spanish speaker in each of the four courses.

In the youngest class, two TEE students were assigned with one of those being a proficient Spanish speaker and one that could communicate a little. The next youngest class had a TEE major, the MET major, and the English major. This class had two good Spanish speakers and one that could communicate a little. The third class had one TEE major, a Spanish Education major, and the Mathematics Education major. They consisted of one proficient Spanish speaker, one that could communicate a little, and one that knew no Spanish. The oldest class had two TEE majors and one Spanish Education major. This class had one proficient Spanish speaker, one that could communicate a little, and one that knew no Spanish.

The first task that the students had was to put together a five-week curriculum for each of the four classes. The students were to teach 90 minutes per day M-F for the five-week period. During the last week of the program, the last two days were reserved for a parent day when the DR students demonstrated projects that they had been working on and a field trip day.

The college students spent the Winter semester and Spring term preparing the curriculum and planning the supplies that they would need for the entire program. From prior years’ experiences, the faculty had learned that nearly all of the supplies would need to be brought from the United States.

The curriculum for the four classes involves a two-year sequence of content for the three oldest classes, and one year for the youngest class. The youngest class consists of beginning DR students to the MACILE program. The other classes are made up of
returning DR students to the program. The following curriculum beginning with the youngest class was designed for the summer of 2012.

- First class – Simple machines and structures
- Second class – Electronics
- Third class – Robotics
- Fourth class – Energy, Medical, and Agricultural Technologies

After returning home, the college students were given an open-ended survey that consisted of the following three questions:

1. What did you learn in participating in both the development and implementation of the program?
2. How did your participation help you prepare for your teaching career?
3. How did your participation effect your own personal development?

A few of the student responses are listed below.

Question 1: What did you learn in participating in both the development and implementation of the program?

- In developing curriculum and materials to be used in the program I was able to discover new ways of teaching the needed principals on a tight budget and with limited supplies. For example we had to take into account the shortages of computer access that would be available to us in the classroom as well as for the students at home. This factored into more hands on models, drawings, or pre-printed photos to show the student what a simulator or Internet research would have otherwise. I also learned in implementing our plan the constant need to add to, revise, adjust to needs and completely change at times the lessons or aspects of them to better fit the needs of the students.

- What I learned in participating in the development and implementation of the program was to plan, prepare, and organize so that an effective learning atmosphere and experience could be provided. I learned specifically how to coordinate with professors and the other teachers so that responsibilities were divided and everyone was involved. I also learned how to break down the processes of development and implementation so that they could be executed and monitored in an efficient manner.

- I learned that there is way more planning involved than I ever imagined. I knew that we would have a lot of work to do, but I never thought it would be so time consuming. I also learned that you really need to think everything through as thoroughly as possible. It helps when you are overly prepared and have thought of every situation that could happen while teaching.

- I learned a great deal when it came to "development". Since we had to plan out our entire course and plan all the lessons in advance, it helped me as a future teacher understand what I really need to have ready before teaching. Second, the fact that we had to gather materials/plan for materials in advance made me realize

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1 The particulars (i.e., unit and lesson plans, with associated instructional activities and assessment rubrics) were not included in this paper due to length restrictions. However, all materials are available for free download from the author's website.
how much we can actually save up and reuse as well as how costly and time consuming acquiring materials could be. This will be helpful in the future when I am teaching. I also learned some awesome class management skills during the implementation.

- From participating in the development and implementation of the program I learned content, teaching strategies, and teamwork. My particular course was composed of 3-team teachers, including myself. Two of us were not technology majors and were not exposed previously to the content we would be teaching. As I was planning and learning the course, I was able to understand the content better, understand and be aware of student misconceptions, and feel more confident in explaining concepts as we taught. Each of us had different skills we could offer to our classroom. As a member of the team, I had the opportunity to learn to work and plan with others. Each of us had the desire to work our hardest to provide a good experience for the students we would be teaching. Because we all had the same goal, the time that we needed to put in and spend with planning and implementation was well worth it and the students could tell we wanted to do a good job.

Question 2: How did your participation help you prepare for your teaching career?

- It has really given me a chance to experience and test out classroom management techniques as well as formative and summative assessment skills. It also gave me the opportunity to write and put into practice an entire section of a course at one time.

- My participation in the program gave me experience with another content area and method of teaching that helped me to expand my understanding of effective teaching strategies. Working with highly motivated students and teachers was inspiring and gave me a vision of what the classroom experience can be like when the right attitudes, beliefs, and expectations are nurtured. I believe I came to appreciate collaboration more highly because I realized how difficult being a teacher is when doing it all on your own. Learning how to have conversations with other teachers and address every day issues of teaching with others was excellent preparation for a future career. I believe that this program provides real hands on experience that is invaluable in the insight that it provides into what value the profession has and can hold for those who decide to make it a career.

- My participation in this program helped me become a teacher because that was my role. I was a teacher. I planned and developed curriculum just like a regular teacher. We had our own classroom and our own students to teach. This program showed me what teaching is really like.

- Like I mentioned above, it helped me develop classroom management skills. My students were always very chatty, so we had a fun time channeling all their energy into something we could use in class. Planning activities and lesson content around their culture was also useful and something they enjoyed. Since I am studying to be a Spanish teacher, this helped me overall with making my Spanish better as well as teaching the students English things they wanted to learn.

- I want to become a teacher for the students. I want to be able to show them that they can have a happy life through living honestly. I want students to know that
someone cares about them. I want students to be able to find satisfaction through pushing themselves and doing hard things. This experience has shown me how much influence students and teachers have on each other. From that, I feel I will be a better teacher. I want to manage my classroom in a way that they know I will push them, but that the reason why I set rules and push them is because they are important to me. As much as the content you are teaching is important, more important is to teach to the students.

Question 3: How did your participation effect your own personal development?

• The connection that a teacher makes with the students is always something that can never be quite described. The students had a great impact on the way I look at the world and the decisions that I make as a person. Also the other students and professors that I was able to come to know and work with continue to stay in touch and have become very good friends and sources for help now and in the future.

• My participation continues to help me reflect on my teaching practices and develop as a professional. Personally, I was able to change my attitudes and beliefs about learning and develop a greater awareness of myself as a student and a teacher. A variety of social skills were developed thanks to the opportunity to work in groups and teams. I believe I developed as well in my motivation to teach and to continue to serve globally and in my own community.

• I learned a lot about my teaching style. I’ve never been up in front of my own classroom before that I could call my own. I learned how I like to handle classroom management and curriculum development. I learned how I am in front of an entire classroom full of students.

• I really enjoyed learning a new culture and getting to know a lot of people in the D.R. This was a great experience for me because I learned about another Spanish speaking country and made some great connections with people there and the BYU students that came with us.

• The lifestyle of the students that we taught through the program is much different than my own. I was able to see a different way of life. Most students and their families had nothing compared to what I have. These families showed me that you can find happiness in any type of circumstance. The students focused on school and wanted to become more educated, they were grateful for the opportunity they had to be able to be a part of the summer school program. Leaving BYU with a desire to be a lifelong learner, I want to remember not to take the things that I have, or the opportunity to learn for granted. As a teacher, I want to always keep learning and keep looking for ways that I can take advantage of the opportunity I had to be able to get the education that I have.

In summary, all of the college students experienced significant growth as a result of the DR study abroad program as illustrated by the above comments. Since most of them had not been in the classroom accept to observe, they learned what it was like to develop and teach curriculum, deal with classroom management issues, and assess student learning. They also learned about the need and benefit of a “learning community”, collaborating on teaching ideas, best practices, and curriculum development. In addition to their improved
teaching and group interaction skills, they were also deeply affected socially by the DR students and their environment. Each of the college students expressed a genuine concern for the DR students, and many have continued to communicate with them through social networks.

This paper introduces and discusses the development and implementation of an engineering focused curriculum for junior high and high school aged students in the Dominican Republic. The authors believe many of the findings discussed above are serviceable to others who are interested in developing and implementing curriculum in third world countries, and or where language and cultural barriers may exist. The authors believe endeavors similar to the effort described above are profitable not only to those students receiving the instruction because it introduces them to content and pedagogy they do not receive in their regular education, but also because of the teacher development experiences those implementing the curriculum receive. The authors, and their supporting institution have a profound belief and commitment to international experiences such as the one discussed in this paper because of the mutual benefit to both parties, and because of how such experiences promote the belief and practice of building and becoming a global community, with education being the pivotal component.