Creating a Biomedical Engineering Summer Study Abroad Program in Costa Rica

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Abstract:
Faculty at Duke University created a 6-week summer study abroad program in Costa Rica to allow more biomedical engineers to reap the benefits of study abroad programs. Students could take one of two technical, required engineering courses, either BME 271A: Signals and Systems or Math 353A: Ordinary and Partial Differential Equations, taught by faculty from the university, as well as a Costa Rican culture class where students could enhance their Spanish speaking abilities and visit local Costa Rican cultural treasures. Through this program, nearly 10% of our engineers were able to participate in a study abroad experience while satisfying their course requirements.

The benefits of study abroad are well known: students improve their language fluency, their cultural understanding, and living in another country greatly enhances their ethno-empathy, that is the ability to put themselves in the shoes of someone from another culture. Despite the well-known benefits, very few of our biomedical engineers participated in study abroad prior to this program. The 3 main reasons cited include 1) inability to find courses that receive transfer credit, 2) an overly constrained engineering curriculum, and 3) many program have prerequisite requirements such as language requirements that our engineers cannot satisfy. In this context, our university created a program for students at all levels of Spanish fluency, where students would take either a biomedical engineering course or a math course.

The two technical courses offered were BME ###: Signals and Systems and Math ###: Ordinary and Partial Differential Equations. Both courses are required for biomedical engineers, while the math course is required for all engineers. As part of the program, the students were also required to enroll in a Spanish culture class, which would count for one of their Social Science and Humanities requirements.

As part of the BME course, students traveled to MonteVerde, a cloud forest preserve located in the mountains of Costa Rica where they measured the natural frequency of a selection of hanging bridges using accelerometers. Using that data, they then modeled the bridges as second-order, linear differential equations. In addition, the students walked the cloud forests with a naturalist and recorded bird signals. Using their knowledge gained from the course materials such as Fourier Transforms, correlations, and spectrograms, students wrote code that automatically identified birds.

The technical courses were taught for six weeks, Monday through Thursdays for three hours each day, creating a challenge to both cover the content of the course and keep the students engaged with the material despite the fast paced, already difficult material. In order to keep the students attentive in the BME course, every other day the course had students complete computer labs instead of lectures, allowing the students to experience the material with their TA and professor present. These few adjustments, as well as the addition of the several technical field trips, created a very engaging course that was relevant to both engineering and the Costa Rican environment.

The Pratt in Costa Rica program has completed 2 years of study abroad and the interest in the program has grown. The first year, the program had 20 students participate and the second year our program had 26 students in total. Students expressed a high degree of satisfaction with both courses, as well as with the Spanish culture course that all students were enrolled in. This summer study abroad program has been a valuable and popular addition to the study abroad options for our university and the biomedical engineering department, offering our engineering students a way to experience study abroad that fits with their needs and increases the flexibility of our program.

Motivation for Engineering Study Abroad Program:

Study abroad programs allow students to explore other cultures, develop their language fluency, improve empathy, and alter an individual student's worldviews. Recent studies have indicated that study abroad can increase graduation rates (1) and also increase students' salaries when they apply for jobs (2). Cultural competency, language fluency, and empathy development are skills that engineers need to develop, yet most engineering programs are so engineering focused, with significant emphasis on course content and coverage, that they have no language requirement. Thus, many engineers graduate without language fluency. For this reason, study abroad programs are perhaps even more important for engineers than non-engineers. Despite this knowledge, engineering study abroad programs are not as prevalent as non-engineering study abroad programs and engineering students are less likely to complete a study abroad program as part of their undergraduate degree (3). At #### University, our biomedical engineers typically need to anticipate a study abroad experience years in advance, and even then are often only able to study abroad their junior fall if they want to take technical courses during their study abroad. Other summer study abroad experiences exist in the university but only for non-technical courses, and none in engineering. If students are interested in pursuing such an opportunity, we encourage them to meet with their Academic Deans who can detail a schedule the students can follow to achieve all their goals. Oftentimes students have to prioritize pre-med requirements over study abroad experiences. Students that come back from a semester away, while they enjoy the experience, typically indicate that the course content was less than rigorous and that they have to perform significant amounts of work to catch up to their peers who did not study abroad. Since our students are also more likely to be pre-health, their schedules are even more constrained and they find it even more difficult to complete a study abroad. We set out to develop an engineering summer study abroad program so that our biomedical engineers, regardless of their career goals, could fit a study abroad experience into their undergraduate degree and reap the many benefits of such a program without falling behind in their studies, while still maintaining the rigor we expect.

Course Selection:

Having been convinced of the value of creating a summer abroad program, we needed to evaluate all the required courses in our curriculum to determine which course would make the most sense to offer abroad. The following 3 primary criteria were used to select the course: 1) lack of required wet labs since the presence of wet laboratories would significantly increase the expense and the difficultly in locating an appropriate site for the study abroad; 2) availability

and interest of faculty to teach the course; and 3) position in the curriculum. We were most interested in finding a course taught early in the student's 4-year college careers to appeal to the largest population of students and not interfere with internships popular in later years.

For these reasons, BME 271: Signals and Systems, a course that covers convolutions, Fourier Transforms, and Laplace Transforms as a mathematically heavy course was selected as the ideal course for the study abroad program for the three following reasons. The version taught on campus contained no labs, only MATLAB programming assignments which would still be possible abroad. There were ample faculty willing to teach the course. Lastly, students could take it as rising sophomores or juniors so it would appeal potentially to both populations of students and therefore receive large enough enrollments to justify the expense.

Nevertheless, there were significant challenges to be addressed before the start of the program. During a normal semester, the class is taught over twelve weeks and has homework assignments that take 12-15 hours of work. Given the fast pace of a 6-week class that met daily, such homework assignments were intractable and would need to be adjusted for the course to be successful. In addition, the university requires the study abroad program to contain an experience or lab that related to the local surroundings to justify the study abroad experience and this connection needed to be created to enhance the relevance of the study abroad course.

Course Development:

Planning for the study abroad started in the spring of 2015, with a preliminary exploratory visit in the summer of 2016 to determine feasibility, followed by the first year of the program being offered in the summer of 2017 to 20 students (14 in the math course, 6 in the BME course), and again in summer of 2018 to 26 students (19 in the math course, 7 in the BME course). The students who attended the program were mostly freshmen (12 in 2017 and 20 in 2018) with the remainder being sophomores (8 in 2017 and 6 in 2018). For most of the students this program was their first study abroad experience, although a handful of students from both sessions completed a 4 week summer abroad in the summer session immediately preceding this course.

Costa Rica was chosen both for its native Spanish language and for the feasibility of teaching the course during the second summer session, which ruled out much of Europe. Teaching the course during the second summer session was important both for instructor requirements and for allowing students to potentially take the first summer session to cover the necessary prerequisites for their technical courses. In addition, Duke University had other programs in Costa Rica and had already scouted a particular organization that would make development of the study abroad program more straightforward. The enrollment in the courses is constrained by the space available: the largest classroom on site can hold 20 students, and the second largest classroom can hold 16 students. The program could not get bigger than 36 without significant changes to the operating facility.

Students who had financial aid packages could use their aid towards this study abroad experience. Several of the needs based scholarships awarded by Duke University specifically

cover 2 summer sessions of courses and many of those students opted to take this as one of their sessions. The cost of the program was $7484 which included lodging, breakfast, dinner, enrollment fees, and all planned excursions.

Students had their choice of 2 courses, they could either take Math 353: Ordinary and Partial Differential equations, a required course for all engineering majors, or they could take BME 271: Signals and Systems, a required course for the biomedical engineering major. In addition to these technical courses, all students had to enroll in a Spanish culture class, which met for three hours every day Monday through Thursday.

The host institution was a language school, not a university in Costa Rica. The choice to pick a host that specializes in language-tourism, instead of a Costa Rican university, was deliberate. The particular center that was chosen was located in San Jose which was central to tourist destinations for free weekends. In addition, the center had a network of over 200 homestay families who were willing to host our students for the 6-week program and included breakfast and dinner as part of the cost of the program. This allowed the program to be more affordable, and also allowed the instructors who were traveling from the United States to focus on their courses instead of having to overly attend to the logistics of coordinating travel and accommodations. This center was excellent at scheduling private buses for the outings that had been planned and coordinating extra activities and fieldtrips for the students to discover and better understand Costa Rica as part of their Spanish culture class.

Acknowledging the difficulty of compressing a course into a 6-week intensive experience, it was decided that the contact hours would be increased such that students spent three hours/day with their instructor and TA, the first two hours of which were traditional lecture followed by one hour of either a problem set assignment or a programming assignment with TA and instructor present during the sessions. Breaking the lectures up this way helped keep students engaged and gave them extra time to work through problems and programming assignments. Having the TA and instructor present for this hour of class allowed the students to immediately apply material they had covered in class to the real problems they would be required to calculate. In fact, this experience was so beneficial to the students that we worked to replicate it in our traditional, on campus, 12-week course. The 2 specific changes that have been made in the regular course mostly pertain to the homework: instead of fewer, longer homeworks we have migrated to shorter, more frequent assignments; and the homework has been broken into MATLAB programming assignments and mathematical calculation type problems. This segregation has allowed students to master the written material before attempting to master the MATLAB programming assignments that pertain to, and usually are connected to, the written homework assignments. This also has reduced procrastination and required students to have submitted their written work before starting on their MATLAB application.

The MATLAB programming assignments were typically an application of the course content. For example, with discrete convolutions the students were asked to perform discrete convolution calculations by hand and then next day used MATLAB to simulate high, low, and bandpass

filters on their favorite music using discrete convolution. In addition, students applied their knowledge of convolutions to filter images. For correlations, students calculated correlation results by hand and then used the correlation to count and denoise neural spike data. These MATLAB programming exercises were instrumental to the success of their final project where they took several fieldtrips around Costa Rica to get data for their project.

For their final project, students traveled to a cloud forest to take accelerometer measurements on the suspension bridges where they tested their hypotheses on underdamped/critically damped/ and overdamped systems as well as determined the natural frequency of a selection of bridges. They also worked with a naturalist in the early hours of the morning to record over 100 bird calls which they would later use to create a program that would auto-identify a particular species of bird. Their work with correlations, frequency space, filters, Fourier Transforms, and spectrograms was instrumental to the success of their final project, which was self-directed and largely done without help from the faculty and TA.

Course Assessment:

The program has been offered twice, in the summer of 2017 and 2018 and had 20 and 26 students enrolled, respectively, making it one of the larger study abroad experiences our university operates. The course, and the program, received high marks as determined by student satisfaction and course and program evaluations. The course quality was rated 4.86/5 and instructor quality of 5/5 with 5 being 'excellent'; the program itself was given a 4.63/5. Specifically, after completing the program the students indicated that they were more likely to engage with the Spanish language (4.52/5), with 5 being 'strongly agree'; they developed a better understanding of their own culture (4.26/5); they understood cultural stereotypes better (4.34/5); they increased their desire to learn a new language (3.47/5); they improved their Spanish (4.67/5); and they felt that their new found Spanish skills will improve their career opportunities (4.09/5). In addition, the performance on the final exam was well within the normal range: for the 2017 session, the mean was 81.7 and standard deviation was 9.3 (N=6) and for the 2018 session the mean was 80 and standard deviation 7.8 (N=7), whereas the standard semester long course had a mean of 76.3 and standard deviation of 12.1 (N=35). While the exams given were not the same, they were roughly equivalent in difficulty and had the same content knowledge required. The first year all 6 of the BME students went on to take the follow up course that requires Signals and Systems as a prerequisite and were as well prepared as the regular cohort of students: overall course mean for the group of students that took the prerequisite on campus was 81.1 with a standard deviation of 12.9 whereas the overall course mean for the students who took the course abroad with this program had a mean of 81.6 with a standard deviation of 6.5. Of the second batch of students, 3 out of 7 went on to take the follow up course and while their final grades are pending, they currently seem as well prepared as the regular cohort of students with no observable differences. Overall the course and the program were very well received by both students and faculty and it is anticipated the program will continue for the foreseeable future.

Conclusions:

Duke University created a summer abroad program for biomedical engineers taught by Duke University faculty that allowed students to get a 6-week immersive study abroad experience in Costa Rica while taking a required BME Signals and Systems course as well as a Social Science and Humanities Elective course. The program was well received by both students and faculty and has been in operation for two years. This course provides a model for how other universities might be able to implement a similar program to allow their students access to a wider variety of study abroad experiences that they might be otherwise unable to experience due to their highly constrained schedules.

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