Two Course Sequence on Developing Sustainable Technologies and Business Models for Rural Nicaraguans

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Abstract: Nicaragua is the second poorest nation in the Western Hemisphere and has a large population of rural farmers. Villanova University has been working with rural communities for over 10 years primarily in the areas of gravity-fed water distribution system design and health care clinics for community health workers.

More recently, a partnership has been established with the main national engineering university, UNI, in Managua. Through this partnership, we have developed a two course sequence for both UNI and Villanova students to work together on senior design/thesis projects to develop technologies and sustainable business models for those technologies.

The first course was taught in the Spring 2014 term for the first time and included 9 students from Villanova University and 11 students from UNI. The Sustainable Business Models course was taught in the Fall 2014 term for the first time. The students worked in mixed teams of UNI and Villanova students on projects ranging from providing remote access to the Internet to new low cost baby incubator technology.

While the classes have gone well to date and the students have generally been collaborating well, there have been several challenges. These include lack of access to the internet for UNI students, differences in school calendars, lack of coordination of Villanova and UNI project advisors, and cultural differences between the Villanova and UNI students.

Details of the courses will be presented along with the challenges faced in teaching these classes. The sustainability aspects of the two course sequence will be described. Lessons learned and changes to be made in the next iteration of these courses will also be presented.

1   INTRODUCTION

1.1   Background

Villanova University faculty and students have been engaged in service learning projects in Nicaragua for the last ten years. These projects have been centered in the rural communities surrounding the town of Waslala, Nicaragua, located in North Central Nicaragua. These communities comprise about 50,000 people who are primarily farmers. There is very little infrastructure in this region with unpaved roads, no access to electricity in many of the communities and one cell phone tower which provides reception to most of the region but sometimes requires walking 30 minutes to an hour to obtain reception.
For the past ten years, Villanova University's Colleges of Engineering and Nursing have partnered with the local parish in Waslala to design and implement gravity-driven clean-water distribution systems from sources located above the animal grazing line and to impart health education to the community and to volunteer community health workers. More recently, Villanova electrical and mechanical engineers have also traveled to the communities around Waslala to explore power generation using small scale hydroelectric systems.

Four years ago, Villanova University received a Sustainable Vision grant from the National Collegiate Inventors and Innovators Alliance (NCIIA) (now renamed, *Venture Well*) to develop and implement a tele-health system in the region around Waslala to improve access to quality health care for the members of the communities in that region. A system was developed and implemented and details of the project can be found in references [1] and [2]. One of the byproducts of this project was the development of a partnership with the Universidad Nacional de Ingieneria (UNI) in Managua, Nicaragua, the largest and most prominent engineering school in Nicaragua.

It was recognized that there are many needs in the rural communities in Nicaragua and a proposal was written to NCIIA for funding to support the development of technologies to enhance the quality of life for rural Nicaraguans. The proposed project was to develop a two course sequence for both UNI and Villanova engineering students. The first course in the sequence was to be focused on providing the contextual background for students, especially at Villanova University, and orient them towards how to identify technology-based, entrepreneurial projects suitable for rural Nicaraguans. The second course was to be focused on the development of sustainable business models for the base of the pyramid customer. In addition, students would prepare a proposal for their capstone design project in the first semester course and then execute their design work in parallel with the second course on sustainable business model development.

The projects were to be worked on jointly by teams comprising Villanova students and UNI students. NCIIA funded the proposal in January 2013 and the first offering of the first course took place in the Spring 2014 term and the second course was first offered in the Fall 2014 term. This paper describes progress to date on this project.

2   COURSE DESCRIPTIONS

2.1   First Course Structure and Content

During the fall 2013 semester, Prof. Maria Virginia Moncada from UNI took a Sabbatical Leave to attend Villanova University as a visiting professor. During this time, she attended several entrepreneurship classes, including a Creativity and Innovation course, an engineering entrepreneurship class, and a Social Entrepreneurship class. The first two courses were taught in the College of Engineering and the third class was taught in the Villanova School of Business.

Also, during her visit to Villanova University, Prof. Maria Virginia Moncada participated in weekly meetings with Profs. Singh, Dougherty and Klingler to discuss the course content for the first course in the two course sequence. An outline of the week-by-week course content is shown in Table 1. During her visit, she also prepared course materials for the classes related to Nicaraguan culture, technology sectors in Nicaragua, current sustainable development programs in Nicaragua, and the design process.

The course began with an introduction to Nicaragua including its geography, history, culture and politics. The Villanova students were given an assignment after this first class to determine the impact of the country's civil war on the economic development of the country relative to other countries in Central America. The next class in the course focused on a description of various technology sectors in Nicaragua, including the energy sector, especially the renewable energy sector, and the information technology and communications sectors. The third class was an introductory presentation to entrepreneurship presented by Dr. Klingler. The fourth and fifth classes included guest lectures from technology-based organizations, non-governmental organizations (NGO's) and for-profit companies based in Nicaragua. The sixth and seventh classes focused on the design process and understanding the "voice of the customer", respectively. Also, Villanova students acted the roles of rural Nicaraguan and Villanova student to simulate interviewing rural Nicaraguans for learning what their lives are like and to uncover what technologies they could benefit from.

All of these classes from the first semester's course were taught to Villanova students since UNI students were on semester break during this time.

Table 1. Class Schedule for First Course

Date	Topic
Jan. 14	Introduction/Course Overview/ Nicaragua: Geography, Culture, History and Socio-economic Analysis
21	Energy, Environment and Telecommunications Sectors in Nicaragua
28	Introduction to Entrepreneurship
Feb. 4	Current sustainable development programs in Nicaragua
11	Current sustainable development programs in Nicaragua (cont'd)
18	The design process
25	Customer needs/identification/interviewing process
March 4	SPRING BREAK in Nicaragua
11	Project proposal development
18	Project proposal development (cont'd)
25	Project proposal development (cont'd)
April 1	Project proposal development (cont'd)
8	Project proposal development (cont'd)
15	Draft Oral Presentation due
22	Final Oral Presentation
29	Final Written Proposal due

The second half of the semester was spent developing senior design project (Villanova students)/Senior Thesis (UNI) proposals. These proposals were prepared collaboratively by student teams comprising students from both universities. The final deliverables at the end of the first course was a joint project proposal presentation and written proposal describing the project to be developed, proposed functional and technical specifications, budget, timeline and distribution of tasks between the team members. The execution of the project was planned for the summer/fall semesters.

2.2 Nicaragua's Commitment to Sustainable Development

A key element in the educating the students about potential technology project development was to ensure that any technologies proposed offered long term sustainability. As a nation, Nicaragua is committed to sustainable development following the lead of its neighbour, Costa Rica. There are several eco-tourist hotels [3] and centers in Nicaragua and a strong emphasis in renewable energy in the expansion of the national electric grid. Five years ago, the Nicaraguan government recognized that the heavy dependence on bunker oil for the majority of its electrical generation left the country very exposed to market fluctuations in the price of oil. A commitment was made to shift to a strong mix of renewable energy into the energy generation portfolio. The Ministry of Energy and Mines (MEM) came out with a plan to produce >70% of its electrical power by renewable energy by 2017 [4]. Although Nicaragua has the second-lowest GDP per capita in the Latin American and Caribbean region, it was recently recognized by the Inter-American Development Bank in its Climatescope 2013 report as finishing third overall (behind Brazil and Chile) for renewable energy investment with a strong showing in the Enabling Framework and Clean Energy Investment and Climate Financing parameters [5]. Already, up to 50% of electrical power generated in Nicaragua comes from renewable sources including wind, hydroelectric, and geothermal [6]. Nicaragua is also a signatory on the Kyoto Protocol to reduce CO_2 emissions in 2015 to 1990 levels. These commitments to shifting to increasing the renewable energy share of Nicaragua's electrical generation plans were an important aspect that was emphasized to the students as a part of their education about the energy sector in Nicaragua.

2.3 Entrepreneurship Workshop for UNI students

Professors Singh, Klingler and Dougherty traveled to Nicaragua during the first week of January, 2014, to deliver a workshop on entrepreneurship to the UNI students. The 2.5 day workshop built upon an exercise conducted by Prof. Moncada in which the students had to visit a market commonly visited by tourists and interview the people working at the stalls in the market. The students learned topics such as value proposition, "voice of the customer", opportunity recognition, prototyping, elevator pitches, and they heard the life story from a successful Nicaraguan entrepreneur, Vladimir Delagneau, Chairman of Tecnosol. They also heard about tech transfer/business incubation services available through UNI. This workshop also gave UNI students exposure to the Villanova professors and vice versa, another opportunity for relationship building.

When Dr. Singh traveled down to Nicaragua over Spring Break, he was able to reconnect with the students having seen them only two months earlier.

2.4 Second Course Description

The second course on Sustainable Business Models for Base of the Pyramid Customers was taught by Profs. Singh and Klingler for the first time in the Fall 2014 term. The aim of this course was for students to consider how to build sustainable business models around their technologies. The approach was based on the Business Model Canvas developed by Osterwalder and Pigneur [7]. The first half of the semester was spent on going through the different elements of the business model canvas and ways of innovating on the business model canvas. Following the introduction to the topic, students were given in-class exercises related to base of the pyramid scenarios. For example, a lecture was given on the topic of Empathetic Design and the students were then given a scenario of a woman in a rural community cooking over a wood fire stove and were asked to consider, through the approach of empathetic design, to develop an improved wood fire stove and a corresponding sustainable business model.

Two other resources were used in this course – the book "Portfolios of the Poor" [8] which was used to educate students on cash flow and financial management amongst the poor, and the E-Spot Canvas [9], an enhancement to the business model canvas which is more appropriate for some developing world projects (primarily around infrastructure projects).

3 COURSE IMPLEMENTATIONS AND ASSESSMENT

3.1 First Course Implementation

The first course in the two course sequence was implemented for the first time during the spring 2014 semester. The first two classes were delivered to the Villanova students remotely over Skype by Prof. Moncada from her office at UNI. The internet connection was good and she came across very clearly. The third class was delivered on campus by Dr. Klingler and the guest lectures from the NGO's and companies in Nicaragua were also presented over Skype. Finally, the design process was jointly presented by Dr. Singh and Prof. Moncada, with Prof. Moncada presenting over Skype.

Eleven electronic and computer engineering students at UNI were selected to participate in this program. Nine electrical and computer engineering students from Villanova enrolled in the class at Villanova. Prior to the Spring break trip, a Facebook page was set up for the group and the students from each of the universities were encouraged to post messages and biographies on this page. While there was some initial activity prior to the trip, the postings increased tremendously after the students met each other in Nicaragua.

After the first seven weeks of classes, four of the students from Villanova University traveled to Nicaragua with Prof. Singh. After arriving in Nicaragua, the students met with the students at UNI and the initial socializing took place. Over the course of the next week, students and professors from UNI and Villanova travelled together to various sites, including rural locations and did homestays in rural communities. They

got to both interact with each other and with local rural Nicaraguans. A picture of the Villanova and UNI students at the entrance to a Solar Center in Totogalpa is shown in Figure 1.

Figure 1: Villanova and UNI students at the entrance to the Solar Center in Totogalpa, Nicaragua

At the end of the week, a debriefing session was held to discuss the potential project opportunities that had been uncovered and a total of almost thirty projects were proposed. Another important consequence of this visit was the development of close relationships between the UNI and Villanova students.

Both the Villanova and UNI students went through a down-select process to finalize their senior design project choices. They were given almost 30 projects to choose from (based on the ideas and opportunities that they uncovered from their visits to rural Nicaraguan communities). They were asked to fill out a decision matrix where the components of the matrix and weighting of each field were:

1. Project alignment with electrical/computer engineering fields (weighting – 1)
2. Interest in the technology (weighting – 1)
3. Skill set to work on the project (weighting – 1)
4. Social impact (weighting – 0.5)
5. Business opportunity (weighting – 0.7)

Six projects were selected as follows and were assigned students from Villanova University and UNI as follows:

1. Solar charge controller design (one Villanova student, one UNI student)
2. Design of a tele-health and remote education system on a smart phone platform (one Villanova student, two UNI students)
3. Design of a neo-natal incubator (three Villanova students, one UNI student)
4. Design of a local area network to provide Internet access to a school in a remote community (four Villanova students, two UNI students)
5. Design of a solar water pumping system (two UNI students)

The students collaborated effectively over the course of the second half of the semester and presented their projects together with the UNI students presenting over Skype. The Villanova students submitted

their senior design project proposals to the Villanova faculty and the UNI students presented their thesis protocols to the UNI faculty. Each of the proposals incorporated the work of the partner teams into their respective reports.

3.2   First Course Assessment

A short survey was administered to the Villanova students taking the first course after the first four classes. Six questions were asked of the students:

1. Have you developed a good sense of the Nicaraguan context for your senior design project?
2. Do you have a good understanding of the energy and information and communication technologies sectors in Nicaragua?
3. Did you find the presentations from the companies/organizations doing work with rural Nicaraguans helpful?
4. Did you find the presentation technology working in the presentations from Nicaragua?
5. Do you feel that you are starting to connect with the UNI students?
6. Do you have an understanding of the special challenges of working with the "base of the pyramid customer"?

All but one of the questions were very positively answered, particularly question 3. The question that was answered with least enthusiasm was question number 5. However, the situation changed dramatically in this particular regard following the trip to Nicaragua.

At the end of the semester, the Villanova students filled out the normal course assessment surveys. Generally, the students found the class interesting but reported several challenges to working with the UNI students. These are expanded upon in the next paragraph.

The first general area of difficulty was communication. Oftentimes, UNI students did not have access to the Internet at home and sometimes there could be significant delays in responses from them to the Villanova students. Also, Skype calls were sometimes not reliable. Times of the calls were sometimes inconvenient for one or other of the parties. The UNI students had the week of April 14th off for the Easter Holy Week. While Villanova students also had time off for Easter from April 17th to April 21st, they were working in the early part of the week and given that the final proposal and presentation for the Villanova students were due April 29th, this holiday came at a critical part of the semester for the students. Nevertheless, the student groups successfully pulled it all together and gave joint presentations for the final proposals at the end of the spring 2014 term, with the UNI students presenting over Skype.

3.3   Project Design/Prototyping Challenges

The projects were worked on jointly by the two sets of students. Some of the students went down in May 2014 after the term was over and another set of students went down to Nicaragua went during the October 2014 fall break. All but one student in the Villanova university class went down to Nicaragua.

Interestingly, the solar charge controller team made good progress even though the students never met each other - the Villanova student did not travel down to Nicaragua until October 2014 when they were half way through their project design! Regular weekly meetings with the advisors proved important to keep the students on track. The students were also meeting with each other over Skype and Facebook at other times during the week. However, the student advisors at the two universities did not coordinate well and this needs to be rectified in future offerings of the courses.

Another issue that arose was the mismatch of the two university's calendars. The Villanova University students have their major break during the months of June-August, whereas the UNI students have a major break between their semesters during the months of January and February. This led to some lack of coordination during the months of June through August.

A further major problem was limited resources at UNI. Parts were very limited in supply and it was not easy for parts to be shipped there. Furthermore, they had limited access to software tools. Much of the hardware prototyping therefore had to be done at Villanova University with design work done at UNI.

Finally, the students from the two universities had local advisors who did not participate in joint project meetings (although the students did collaborate, primarily communicating over Facebook). As a result, sometimes the two sets of students would get conflicting advice/guidance from their respective advisors. In future iterations of the courses, it will be important to make sure that the advisors of the project teams from the two universities coordinate and provide uniform guidance to the student teams.

3.4 Second Course Implementation

The Sustainable Business Models for Base of the Pyramid Customers course was implemented in the Fall 2014 semester for the first time. The first half of the semester was spent guiding the students through the business model canvas approach and giving the students case studies and in-class/homework exercises to develop their proficiency in using the business model canvas tool. During the second half of the semester, the students were asked to develop their business models and they presented segments of their business model canvas in class. The professors teaching the course critiqued these models and gave them guidance and mentoring to improve them. This was done several times during the second half of the semester. The final deliverables were a final presentation on the final business models and a written business model. Unfortunately, only one student at UNI participated in this class and so only one business model was a joint effort between the two sets of students.

A course survey was conducted at the end of the semester and the course was well received overall, given that it was the first time that it was being taught.

3.5 Sustainable Engineering Design and Development Aspects of the Education

The problems discovered in developing technologies for rural, base-of-the-pyramid community members tend to be complex and require a multi-dimensional, systems thinking approach to determining a solution as opposed to simply a technological solution. The students are forced to examine the individual and societal needs for the communities with which they are working. The dire economic conditions drive solutions as much as the technology itself. Oftentimes, political aspects must also be considered. Many ethical dilemmas arise as solutions are being proposed for these types of customers and engagement with the potential customers is critical in producing a successful solution.

It is also important to ensure that sustainable, locally-resourced materials be incorporated into the design (where possible) to ensure long term maintainability of the designs. As a result, students were forced to consider sustainability in every aspect of their design and led to several design iterations as they incorporated these design considerations into their prototypes. An example of this aspect is in the design of the baby incubator/phototherapy device. Initially, the students developed a very sophisticated heating system to ensure that the baby remains at a constant temperature. However, as the students considered the power needs for such a system, it was clear that the solar panels/batteries required to provide the heating would be very large and expensive. In further iterating on their designs, they considered an electric blanket arrangement. Finally, they ended up coming up with a design in which the baby was using heat from the mother as the primary heat source for the unit.

The opportunity for students to work in multi-national, multi-cultural teams on the projects forced them to examine the motivation and perspectives of others, especially people who come from a very different background than theirs. Especially with the "customers" coming from rural communities, empathy played a key role in considering their designs. Of course, extreme affordability needed to be included in consideration of sustainable business models.

4 Conclusions and Summary

A new two course senior design sequence focused on the development and commercialization of technologies for rural Nicaraguans has been implemented as a joint program between Villanova University and UNI, Nicaragua. The courses were implemented for the first time in the spring 2014 and fall 2014 terms. The courses went well despite many challenges. The students of the two universities bonded well and the communications technology for delivery of lectures over Skype worked very well

The students discovered projects through traveling in Nicaraguan rural communities and interviewing local members of the communities. The student teams worked together remotely to develop their project proposals and subsequent prototype designs and business models.
The face-to-face interaction of the students had a catalytic effect in establishing a good relationship between the students and the students effectively used social media to maintain and further develop those relationships. While there were cultural and language barriers that made the collaboration challenging, the students found a way to overcome these barriers and succeed.

This collaborative project work aimed at base-of-the-pyramid customers forced the students to consider many aspects of sustainable engineering design. These sustainability elements included developing sustainable business models, long term maintainability of devices in the field, use of renewable energy resources to power units in the field, use of locally sourced materials wherever possible, and complex, systems-thinking issues including the ethical and political aspects of the projects. While life cycle analysis was not explicitly covered in the first iteration of these courses, this aspect will be included in the future to ensure students understand how to further enhance the sustainability of their designs.

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