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Development of a New Graduate Course in Sustainable Technology Entrepreneurship for Scientists and Engineers

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Abstract - This paper describes the development of a new graduate level course entitled Sustainable Technology Entrepreneurship for Scientists and Engineers (STESE), which was jointly developed and delivered by the Colleges of Engineering, Business and Agricultural Sciences at Colorado State University. The overarching goals of the STESE course were two-fold: (1) to instill an entrepreneurial mindset and global/sustainable perspective among engineering and science students and (2) to provide technical expertise and rapid product realization resources to student teams within the Global Social Sustainable Enterprise (GSSE) program housed in the College of Business. The motivation behind the first goal was to address a deficiency of adequate entrepreneurship training opportunities for graduate students within engineering and agricultural sciences at CSU. The motivation behind the second goal was to address a critical shortage of engineering and agricultural science acumen within the GSSE teams engaged in sustainable enterprises in developing countries. The latter need was addressed by assigning engineering and science students from the STESE course directly to the GSSE teams. In its first offering, the STESE course was cross listed between the Colleges of Engineering and Agricultural Sciences, which yielded a total enrollment of 40 students among 6 different majors. The course was jointly taught by faculty from three departments (Management, Mechanical Engineering and Agricultural Resource Economics) in a weekly format that included lectures, project based learning, and guest speakers. The 16-week semester was divided into four general topic areas: the entrepreneurial mindset, product realization, opportunities at the base of the global economic pyramid and new venture management. Student evaluations from the first offering of the STESE course strongly suggest that the students gained valuable exposure to commercialization opportunities for their graduate research along with the recognition of the potential opportunities at the base of the global economic period. The slate of guest speakers was overwhelmingly evaluated as the most valuable aspect of the course. The project component of the course was generally viewed less favorably.

1. Introduction

Beginning with its pioneering work in development of the Peace Corps [1,2], Colorado State University (CSU) has had a long history as a leader in international development. Today, as one of America's top land grant universities, CSU has built strong research programs in environmental science, energy, agriculture, and infectious diseases. To leverage these research strengths toward a focus on the United Nations Millennium Goals [3] (e.g. end poverty and hunger, universal education, child health, environmental sustainability, etc.), the College of Business at CSU recently created the Global Social and Sustainable Enterprise Program (GSSE).
The GSSE program is a unique Masters program that provides business students with the skills and experience necessary to build and manage sustainable enterprises in developing countries. The GSSE admits a cohort of 25 students each year (50 percent international and 50 percent North American) who form teams that work on international enterprise development projects that address real world problems in developing countries [4]. Recent projects include a distribution network for solar lights and radios (Ghana and Peru), small engines for economic development (Bangladesh, Ethiopia), mobility aids and training (Zambia), hydraulic hybrid technology transit buses (India) and biodiverse products from wildlife-friendly agriculture (Cambodia).

Solutions to these problems often require development of new technologies, implementation of existing technologies in a novel developing economy context or development/implementation of new ecological and economic approaches. The initial offering of the business-based GSSE program did not include a formal means of interfacing GSSE students with capable and interested engineering and agricultural science students at CSU. Rather, any such interfaces between GSEE teams and engineering/science students were achieved on an ad hoc basis and resulted in varying degrees of success. Accordingly, in 2009 a Course and Program Grant was obtained from the National Collegiate Inventors and Innovators Alliance (NCIIA) to formalize a linkage between GSSE Masters students and graduate students within the College of Engineering (COE) and College of Agricultural Science (CAS), respectively. The NCIIA grant has facilitated the development of a new program in sustainable technology-based entrepreneurship for graduate students in the COE and CAS. The objectives of the new program are twofold:

1. Instill an entrepreneurial mindset and global/sustainable perspective among students who typically enter graduate school with a myopic technical focus.

2. Provide valuable engineering/agricultural science expertise and rapid product realization resources to enterprise teams within the GSSE program.

Now in its second year, the objectives of the new program are being met through the development of a new graduate level course entitled Sustainable Technology Entrepreneurship for Scientists and Engineers (STESE), which is cross-listed between COE and CAS, and team taught by the authors of this paper. As described herein, in its initial offering in Spring 2010, COE and CAS graduate students were exposed to the fundamentals of technology entrepreneurship in the context of developing economies [5]. During this first offering, multiple student teams from among those enrolled in the course were assigned to an existing GSSE team where they were responsible for identifying/implementing appropriate technologies, ecological systems and economic approaches for the GSSE enterprise.

The new program is addressing two important needs at CSU. The first need is to address the current deficiency of adequate entrepreneurship training opportunities for graduate students within the COE and CAS. Numerous startup companies have spun out of COE and CAS in recent years [6,7,8,9,10] by graduate students and faculty with good ideas but with little formal business training. And, while a wealth of business expertise and curriculum exists within the GSSE program and the College of Business (COB) at large, it is rarely feasible for engineering and science graduate students to take advantage of these resources given the intensity of the graduate curriculum in their own technical discipline. The new program condenses the material from multiple offerings within the COB and does not require any prerequisites.
As mentioned above, the second need addresses the critical shortage of engineering and agricultural science acumen within the GSSE teams engaged in sustainable enterprises in developing countries. The latter need has been satisfied by assigning engineering and science students directly to the GSSE teams and rewarding them with graduate credits that count toward their technical degree. As the program moves forward, it is anticipated that the majority of the technical students will lend a valuable hand for a semester and continue on with their graduate research in an unrelated area. Such students will benefit from an exposure to the entrepreneurial mindset, recognition of global/sustainability issues and introduction to business skills. In some cases, however, it is anticipated that the technical students will stay on with their GSSE team and pursue a graduate degree based on technical research related to the GSSE project.

2. Planning the STESE Course and Program

In its initial planning stages, the new program relied heavily on other existing strengths at CSU in international development, global sustainability, and an established record of transforming laboratory research into innovative startup endeavors to benefit the human condition on a global scale. Specifically, these areas include:

- A burgeoning undergraduate entrepreneurship curriculum within the College of Business,
- The newly developed School of Global Environmental Sustainability and
- The Global Innovation Center (GIC) for Energy, Environment and Health.

Each of these resources is discussed briefly below.

Entrepreneurship Curriculum within the College of Business

One of the main components of the new program was the development of the STESE graduate course. To develop the course sequence, the authors worked closely with faculty members who are part of a burgeoning entrepreneurship program within the COB. Course content that is specific to global sustainable enterprises was developed in consultation with faculty members who were actively involved in the GSSE program and in the entrepreneurship certificate program for undergraduate students [11]. Specifically, in its first offering, course content for the STESE course was culled and/or course syllabi were shared from the following existing courses within the COB, which span from the 200 to the 600 level:

- Social, Ethical, and Regulatory Issues in Business (BUS 260)
- Fundamentals of Entrepreneurship (MGT 340)
- New Venture Creation (MGT 420)
- New Venture Management (MGT 440)
- Social Entrepreneurship and Sustainable Business Strategies (MGT 496)
- Global Social and Sustainable Entrepreneurship (MGT 667)
- Financing and Evaluating the Sustainable Enterprise (BUS 669)

In addition to the collegiality amongst faculty from the three colleges, support was garnered from the respective Department Heads and Deans as well. Indeed, although two of the three instructors were teaching this first offering as a voluntary overload, their Department Heads were in full support of the endeavor.
Successful implementation of the new program required effective collaboration between faculty members within three separate colleges at CSU. This relationship has been stewarded by a new umbrella organization, developed specifically to foster this type of multidisciplinary program development. Unveiled in July 2008, the CSU School of Global Environmental Sustainability (SOGES) [12] was created to streamline the university's internationally recognized environmental research programs and to prepare students for the growing "green" workforce. The goal of SOGES is to facilitate new collaborations that transcend traditional faculty disciplinary boundaries and to encourage intellectual advancement in real-world innovations. Each of the STESE course instructors are Affiliated Faculty Members of the new School and future offerings of the course will be cross listed under the SOGES heading.

The Global Innovation Center for Energy, Health and the Environment

Successful implementation of the new program also required dedicated facilities for project-based learning, rapid prototyping and testing in an environment with a successful track record in solving multidisciplinary problems. Accordingly, dedicated workspace was provided within the Global Innovation Center for Energy, Health and the Environment (GIC) at CSU. Housed within the Engines and Energy Conversion Laboratory (EECL) [13], the GIC was founded in 2005 to facilitate solutions to energy, environmental and health problems in the developing world through the formation of innovative business structures that disseminate these products on the widest appropriate scale. The GIC has played a central role in facilitating the spinoff of a variety of CSU-related business ventures such as Envirofit [9] and Solix Biofuels [10]. Figure 1 shows an example of the GIC approach wherein research on clean cookstoves at the EECL (Fig. 1a) was transformed into a viable product (Fig. 1b) by the non-profit corporation Envirofit, which recently partnered with the Shell Foundation to produce and sell 10 million clean-burning stoves over the next 5 years.

![Figure 1 (a) Cookstove research at CSU and (b) the Envirofit S-2100 cookstove in use in India.](image)

Putting it All Together

The new program, which represents a partnership between three separate colleges at CSU, aims to formalize a process for collaboration on technology-based entrepreneurship that heretofore has taken place only informally and with varying degrees of success. As depicted in Fig 2, the new
program enables the three colleges to readily collaborate on global sustainable enterprise projects via the existing Global Social Sustainable Enterprise program (GSSE). Opportunities for these enterprises are generated through international field work from GSSE teams and/or R&D efforts within the COE and CAS. The resources (facilities, expertise) necessary to provide technological solutions to these problems are provided via the Global Innovation Center (GIC). The STESE course is the conduit whereby engineering and agricultural science graduate students obtain credit for working on these projects while simultaneously benefiting from training in the fundamentals of entrepreneurship. As indicated by the dashed lines, the efforts will be sustained through the recently unveiled School of Global Environmental Sustainability [6] and possibly a proposed School of Innovation and Entrepreneurship concept which is currently under consideration. Indeed, the new program is serving as a pilot program for future collaborative efforts via such a School of Innovation and Entrepreneurship.

Figure 2. Schematic diagram showing how the new STESE course and program fits in with the other campus initiatives.

3. Curriculum Development

The new program was modeled after similar, highly successful programs currently offered at other universities that focus on providing entrepreneurial training to traditionally technically-oriented graduate students. At Princeton University, for example, High-Tech Entrepreneurship (ELE 491/591) has been offered for the past decade to undergraduate seniors and first-year graduate students [14]. This project-based course introduces students to the actions required to launch a successful high tech company, addressing topics such as: evaluating technologies for commercial feasibility, determining how best to launch a new venture, attracting the resources needed to start a company, preparing comprehensive business plans, structuring business relationships, and managing early stage companies. The Princeton course is one of the most popular courses in the School of Engineering and Applied Sciences (over 900 students enrolled in its first 5 years) and has garnered 5 teaching awards for its creator, Prof. Ed Zschau.
The Center for Entrepreneurship at the University of California-Davis (UC Davis), headed by faculty director Andrew Hargadon, runs a Business Development certificate and an Entrepreneurship Academy [15] for this same purpose. The Entrepreneurship Academy is a one-week, intensive business development program for science and engineering doctoral students and postdocs interested in commercializing their research and launching a new venture. At UC Davis, the following topics are taught by venture capitalists, angel investors, entrepreneurs and UC faculty members: innovation strategies/work practices, evaluating technology/market opportunities, IP and licensing strategies, building the team, finance/investment strategies and rapid prototyping/testing strategies.

The new program differs slightly from the aforementioned programs in that it focuses heavily on opportunities “at the base of the pyramid,” which refers to the 4 billion people in the world with annual purchasing power under $1,500. As argued by renowned business strategist C.K. Prahalad [5], the market at the base of the pyramid has the potential to be the engine for the next round of global trade and prosperity “if we stop thinking of the poor as victims or as a burden and start recognizing them as creative entrepreneurs and value-conscious consumers.” By introducing technologically focused graduate students to opportunities at the base of the pyramid, the possibility exists to develop solutions that are not merely economically viable but might also impact humanity on a grand scale. As Nobel Peace Prize laureate and microcredit pioneer Muhammad Yunus points out [16],

"...the poor, once economically empowered, are the most determined fighters in the battle to solve the population problem, end illiteracy and live healthier, better lives."

The major curriculum development effort for the new program entailed determining the best possible content for the STESE course, which would be cross-listed between COE and CAS, and team taught by the authors. Table 1 contains an outline of the course content that was originally contemplated for the first offering of the STESE course. As shown in the table, the course covered 5 main focus areas: entrepreneurial mindset, opportunity identification, opportunity assessment, opportunities at the base of the pyramid and new venture management. The course content was culled from a variety of existing courses within the COB, the syllabi of which were generously provided to the authors from multiple instructors within the COB. Delivery of the course content would be accomplished via lecture, project based learning, case studies and guest speakers. Guest speakers would include principals from the traditional Fort Collins business community, the Colorado sustainable energy community and CSU global sustainable enterprises.

Table 1. Original plan for course content for the STESE course.

<table>
<thead>
<tr>
<th>Week</th>
<th>Focus Area</th>
<th>Content</th>
<th>Existing Course(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Entrepreneurial</td>
<td>Introduction, historical perspective,</td>
<td>MGT 340</td>
</tr>
<tr>
<td></td>
<td>Mindset</td>
<td>entrepreneurial mindset</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Entrepreneurial</td>
<td>E-ship and the economy :A global</td>
<td>MGT 340</td>
</tr>
<tr>
<td></td>
<td>Mindset</td>
<td>perspective</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Opportunity</td>
<td>Recognizing opportunities and generating</td>
<td>MGT 340</td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td>ideas</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Opportunity</td>
<td>Intellectual property protection</td>
<td>MGT 340, MGT 420</td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Opportunity</td>
<td>Market and Customer: Business Model and Value Chain</td>
<td>MGT 340</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Implementation

The first offering of MECH/AREC 581 - Sustainable Technology Entrepreneurship for Scientists and Engineers – occurred in the Spring 2010 semester. The course was team taught by the authors of this paper. Given the experimental nature of this first offering and the limited time for advertising its existence, it was anticipated that enrollment would likely consist of 15 to 20 students. However, a total enrollment of 40 students was achieved among 6 different majors. The formal meeting time for the class consisted of a single weekly 3-hour block, which was typically split into 3 separate sub-blocks that consisted of lecture, activity and guest speaker. As will be discussed below, the team project was a major component of the course and accounted for over 50 percent of the grade for each student.

Given the expertise of 3-person instructor team and the various constraints (travel, guest speaker availability) the ultimate course schedule and content deviated slightly from that originally contemplated in Table 1. The 16-week semester was divided into four general topic areas: the entrepreneurial mindset, product realization, opportunities at the base of the pyramid and new venture management. Table 2 contains the list of content for the 16-week schedule. Included in the table are the required readings and the slate of guest speakers. The two main sources for the required reading were as follows:


In addition to these sources, a variety of other articles were assigned each week, as detailed in Table 2. Also, each student was required to select a book of their choosing that related to the theme of the course and present a “book report” to the class during Week 6. Later in the semester, each student was required to read an annual report of a company (or non-profit entity) engaged in operations in the developing world.
### Table 2. Final course content for MECH/AREC 581 – Sustainable Technology Entrepreneurship for Scientists and Engineers.

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic(s)</th>
<th>Readings</th>
<th>Guest Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Innovation, Entrepreneurship, and Development</td>
<td>Nidumolu, Prahalad, &amp; Rangaswami [17]</td>
<td><strong>Bryan Willson,</strong> Co-Founder, Envirofit International; Co-Founder, Solix Biofuels</td>
</tr>
<tr>
<td>2</td>
<td>Idea Generation and Entrepreneurs</td>
<td>Polak[18], Intro, Ch. 1-3 Millennium Development Goals [3]</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Envirofit Case Study</td>
<td>Polak [18], Ch. 4-5 Envirofit Case Study [19]</td>
<td><strong>Nathan Lorenz,</strong> VP Engineering, Envirofit International</td>
</tr>
<tr>
<td>4</td>
<td>Identifying Customer Needs and Market Analysis</td>
<td>Polak [18], Ch. 6-7 FastTrac [20] Ch. 2-3 Ulrich and Eppinger [21], Ch. 4</td>
<td><strong>Stephen Schmutzer,</strong> Co-Founder, Firefly Medical</td>
</tr>
<tr>
<td>5</td>
<td>Business Model and Metrics</td>
<td>Polak [18], Ch. 8-10 FastTrac[20] Ch. 4, 6,</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><em>In class book report discussion</em></td>
<td>None</td>
<td><strong>Lou Bucelli,</strong> Bucelli and Co, LLC.</td>
</tr>
<tr>
<td>7</td>
<td>Product Specifications</td>
<td>Ulrich and Eppinger [21], Ch. 5</td>
<td><strong>Ken Petersen,</strong> professor of supply chain management, CSU College of Business</td>
</tr>
<tr>
<td>8</td>
<td>Network and Partnerships</td>
<td>Polak [18], Ch. 11-12</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Spring Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Design for Sustainability</td>
<td>Otto and Wood, Ch.15.</td>
<td><strong>Justin Discoe,</strong> Co-Founder, Sprig Toys</td>
</tr>
<tr>
<td>11</td>
<td>Design for Affordability</td>
<td></td>
<td><strong>Paul Polak</strong></td>
</tr>
<tr>
<td>12</td>
<td>Ethical, Political and Regulatory Aspects</td>
<td>FastTrac [20] Ch. 8</td>
<td><strong>Scott Deeter,</strong> CEO, Ventria Bioscience</td>
</tr>
<tr>
<td>13</td>
<td><em>In class Organizational Profiles discussion</em></td>
<td>None</td>
<td><strong>None</strong></td>
</tr>
<tr>
<td>14</td>
<td>Intellectual Property</td>
<td>FastTrac [20], Ch. 8 Mutschler &amp; Graff [22]</td>
<td><strong>Tim Reeser,</strong> COO, Cynergy.</td>
</tr>
<tr>
<td>15</td>
<td>Ownership, Compensation, Funding, Stages of Growth and Exit</td>
<td>FastTrac [20] Ch. 7 and 9</td>
<td><strong>Catherine Merigold,</strong> General Partner, Vista Ventures</td>
</tr>
<tr>
<td>16</td>
<td>Final Presentations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Guest Speakers

As listed in Table 2, a total of 10 guest speakers contributed to the Spring 2010 STESE course. These speakers included a CSU faculty member who founded several companies (Bryan Willson), successful entrepreneurs from the local Ft. Collins community (Steve Schmutzer, Justin Discoc, Scott Deeter), a serial entrepreneur (Lou Bucelli), a university technology transfer professional (Tim Reeser), and IDE founder Paul Polak. Without exception, each guest speaker was inundated with questions from the students after their presentations and student evaluations were universally emphatic in their praise for the slate of guest speakers. The inclusion of IDE founder and author Paul Polak was a particular highlight of the course since the students had read his book and almost all of the team projects focused on opportunities at the base of the pyramid and/or design for affordability.

Team Projects

As mentioned above, one of the main objectives for the new program was to use the STESE course as a means of assigning engineering/agricultural science students to existing GSSE teams. Given the class size for the first offering of STESE, however, it immediately became clear that it would not be possible have all student teams assigned to a GSSE team. Accordingly, it was decided that each student would propose their own project, while each faculty member would champion one of the GSEE projects in need of engineering/agricultural sciences support.

During the third week of class, each student was provided with the quad chart template shown in Fig. 3, which would be the means by which they would elucidate their own project idea to the class. Similarly, the faculty members developed quad charts for the available GSSE projects. The following week, each student and faculty member was given 1 minute to orally present their quad chart to the class. After each student and faculty member presented their project concepts, all of the quad charts were mounted on the walls of the classroom. Students were then provided with Post-It notes and instructed to vote for the 5 projects that they deemed to have the best chance of success and to which they would prefer to be assigned.

Using this process, a total of 9 projects were selected and project teams were created with 3 to 5 students in each team. The selected projects, which included 3 GSSE projects, are listed in Table 3 along with the opportunity statement developed by each team. The projects highlighted in orange are those that directly supported an existing GSSE team. Projects highlighted in blue represent those that were evaluated by the faculty as viable opportunities for future GSSE teams. A total of 60 percent of the semester grade was directly related to the team project. The team project assignments consisted of the following:

- Project Proposal
- Market Analysis/Plan
- Design Brief
- Final Presentation
- Final Written Summary.
The team projects resulted in varying degrees of success. Some of the student-generated projects were very strong, both in terms of the initial opportunity analysis and subsequent preliminary design concepts. For example, projects such as the small scale wind power/irrigation system and village energy storage system using recycled batteries from hybrid electric vehicles were evaluated by the faculty team as viable for future GSSE teams. Whereas some of the other project teams struggled to clarify the opportunity and/or develop a conceptual design responded to that opportunity. In terms of the projects that were assigned to existing GSSE projects, these too resulted in varying degrees of success. In the case of SEED, which is a GSSE company engaged in manufacturing small diesel pumpsets, the project was too far along for the STESE students to effectively contribute to the market plan and opportunity analysis. The team did, however, ultimately provide valuable engineering design support by developing a strong configuration design that was subsequently field tested in Bangladesh. Conversely, the Thin Air GSSE project, which consisted of developing small nitrogen-fixing cyanobacteria cultivation systems (i.e. open bonds) for the development of bio-fertilizer, was too early in its developmental stage. As a consequence, the GSSE team was unable to provide adequate specifications on the cyanobacteria biological process which made it difficult for the STESE students to adequately utilize their design skills to develop a realistic cultivation system.

Figure 3. Template for quad chart used in the project selection process.
Table 3. Project titles and opportunity statements from Spring 2010 STESE course.

<table>
<thead>
<tr>
<th>Project Title</th>
<th>Opportunity Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Point</td>
<td>Provide a branding label indicating purified water for tourists traveling in India and locals living in well-traveled areas. Develop a fair pricing differentiation scheme based on quantity purchased.</td>
</tr>
<tr>
<td>Grounds for Change</td>
<td>It is necessary for producers to reduce the time of drying and losses in production due to contamination during the coffee drying process.</td>
</tr>
<tr>
<td>Pine Beetle Power</td>
<td>Selling locally grown Colorado beetle-killed pine biomass for residential and municipal heating needs.</td>
</tr>
<tr>
<td>SEED (Small Engines for Economic Development)</td>
<td>The engineered 2HP diesel pumpset will give small scale farmers (≤2.5 acres) the opportunity to purchase a cost effective and easily portable device which can meet their irrigation needs.</td>
</tr>
<tr>
<td>Simple Solar Irrigation Pumps</td>
<td>Labor free irrigation with increased capacity and well depth provides the small farmer with an attractive invest opportunity for higher productivity and profits.</td>
</tr>
<tr>
<td>MicrobeSeed</td>
<td>MicrobeSeed is a bioengineered microbe mix and municipal waste vehicle retrofit capable of increasing landfill gas production rates for methane generation.</td>
</tr>
<tr>
<td>Thin Air</td>
<td>An engineered, sustainable, accessible nitrogen fertilizer for small Ethiopian farms.</td>
</tr>
<tr>
<td>Village Energy</td>
<td>A scalable energy distribution network for families without electricity in India.</td>
</tr>
<tr>
<td>Upepo Maji Uhuru: Small Scale Wind Power</td>
<td>A simple, low-cost, wind-powered water pump can be made that enables increased income through irrigation while limiting the manual labor required.</td>
</tr>
</tbody>
</table>

5. Assessment

The first offering of the MECH/AREC 581 STESE course culminated in May 2010 and assessment began immediately thereafter in preparation for the second offering in Spring 2011. Assessment included course evaluations from the 40 students enrolled in the course, exit interviews with select graduate students and initial compilation against outcomes assessment metrics that were originally developed when the grant proposal was submitted to the NCIIA.

STESE Course Evaluations

Student evaluations were compiled from the 40 students enrolled in MECH/AREC 581. Based on both the numerical scores and the valuable student comments, it is apparent that there was a consensus that the faculty members “gave it the old college try” to develop a quality product. The guest speakers were definitely a highlight but the project and the textbook were not viewed as favorably. In terms of numerical scores, 14 percent answered “strongly agree” and 86 percent answered “agree” to the question “Overall, I would rate this course as good.” The ratings for the
faculty members themselves were even stronger than the course ratings. For example, 44 percent answered “strongly agree” and 56 percent answered “agree” to the question “Overall, I would rate this teacher as good”. And, 69 percent answered “strongly agree” and 31 percent answered “agree” to the question, “The teacher was enthusiastic about the course.” Several of the comments are included below:

I like the speakers! Fast track [the textbook] was very expensive and may be unnecessary. Reading load was a bit much.

Good course overall. One thing I would change is the addition of class discussion about the reading material. It was interesting, but I think most of the students stopped reading after the first few weeks. Speakers were a beneficial addition to the class.

I think the course provided a real eye-opener for students that a whole other type of career/endeavor exists. It was also highly motivational for. The difficulty (obviously) is teaching multiple subject areas to multiple backgrounds (ag, ME, other eng, econ, business, etc.). In particular, I think this class would be best suited for motivational/awareness with less time devoted to design for the BOP - maybe make that a separate course? Maybe include more biz/legal/practical advice. Also, I’d either cap enrollment at 20 or change some of the in-class activities.

I liked the overall setup of the course. I preferred to have the guest speaker towards the end of the lecture. Quizzes would have helped my understanding.

Enjoyed the diverse speakers. The course manual was not used enough for the $150 cost. Would have been helpful to have a lecture on basic business.

[I recommend] two classes per week. Outline for presentations (guest speakers) to interact with so to design some parallels between each (and observe various opinions about different topics from class).

Considering this was the first time for this course, it was good. There were a few bugs that needed to be worked out with communicating HW assignments a little more clearly. The guest speakers were good (especially the toy guy).

I greatly enjoyed this course. My favorite part was the outside speaker sessions, especially the variety really helped. Some were encouraging, some bluntly talked about the challenges. Please come to class prepared. Thanks for bringing Paul Polak. It was excellent. The group project was really helpful. Unfortunately, I don’t think ours will get anywhere. But it would be awesome if somebody’s did.

Based on the student comments, there was a consensus that the large class size (40 students) was problematic for effectively conducting the in-class exercises. We had originally expected approximately 10 to 20 students for the first offering but we capped enrollment at 40 students, which was the maximum limit for the classroom assigned to the course. To our surprise, enrollment swelled to approximately 40 students in the first offering with 20 students officially enrolled in MECH 581, 15 students officially enrolled in AREC 581A2 and a handful of auditors.
As is often the case with team-taught courses, the course required a lot of initial planning. Moreover, we were attempting something that had never been done, which was to squeeze the three topical areas of product design, intro to entrepreneurship and opportunities at the base of the pyramid into a single course. As the written comments suggest, the students generally agreed that the overall objectives of the course were admirable and that the instructors made a strong effort in this first offering. A substantial minority of the students indicated that the topical areas were too diverse and should be focused more closely toward providing engineering/science students with an introduction to entrepreneurship. The cadre of guest speakers that we lined up for the course was overwhelmingly viewed as the highlight of the course.

Based on the comments, there are some key areas for improvement. The textbook was not rated highly, the size of the class was too large, the format was not optimal (once per week for 3 hours), and the semester-long project needs work. Interestingly, one student commented that the instructors were unorganized as evidenced by our having to huddle at the beginning of most classes to develop a game plan for the 3-hour class. The reality is that the instructors spent substantial amounts of time preparing for this class (via meetings, emails and phone calls) but we would discuss the timeline for the planned events for the day - which typically included a lecture, an in-class activity and a guest speaker – in front of the class at the beginning of the lecture. The comment that we were unorganized is a lesson that impressions are very important. Clearly, it looked like we were unorganized to some students and that impression diminished the quality of the course for those students.

**Longer Term Assessment**

In developing the evaluation and sustainability plan for the NCIIA grant, the following metrics were identified for assessment to evaluate the success of the program:

- Number of COE and CAS graduate students per year enrolled in the first semester STESE course.
- Number of COE and CAS graduate students whose master’s/Ph.D theses are related to a GSSE and/or STESE project.
- Percentage of GSSE projects that result in successful startup ventures prior to advent of the new program.
- Percentage of GSSE projects that result in successful startup ventures after to advent of the new program.
- Percentage of engineering and agricultural science graduate students who participated in the program who are involved in startup ventures within 5 years, 10 years, 15 years after graduation.

Table 4 contains a list of preliminary program goals for each metric listed above that were identified at the initiation of the NCIIA course and program grant. In Table 4, the outcomes that have exceeded or met expectations are highlighted in blue, the outcomes that are below the expectations are indicated in orange and those that have yet to be assessed are highlighted in green. Clearly, the overwhelming majority of these metrics will require longer term evaluation. However, given the number of students who enrolled in the first offering of the STESE course,
the program is off to a solid start. Indeed, the initial goal of 25 students enrolling in the first STESE course was far exceeded given the enrollment of 40 in the first offering of the course. The number of COE and COS students whose masters or PhD theses are directly related to a GSSE and/or STESE project did not meet expectations for year one. In retrospect, this outcome was overly ambitious for the first year.

Table 4. Program outcomes and preliminary goals of the STESE course and program.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of COE and CAS grad students per year enrolled in first-semester STESE course.</td>
<td>Year 1: 25, Year 3: 40, Year 5+: 40</td>
</tr>
<tr>
<td>Number of COE and COS grad students whose master’s and/or Ph.D theses are directly related to a GSSE and/or STESE project.</td>
<td>Year 1: 6, Year 3: 10, Year 5+: 10</td>
</tr>
<tr>
<td>Percentage of GSSE projects per year that result in successful startup ventures before the advent of the proposed program.</td>
<td>Year 1: 10%, Year 3: NA, Year 5+: NA</td>
</tr>
<tr>
<td>Percentage and number of GSSE projects per year that result in successful startup ventures after the advent of the proposed program.</td>
<td>Year 1: NA, Year 3: 25%, Year 5+: 33%</td>
</tr>
<tr>
<td>Percentage of COE and CAS graduate students who participated in the program who are involved in startup ventures 5 years, 10 years, 15 years after graduation.</td>
<td>Year 1: NA, Year 3: NA, Year 5+: 5%, 15%, 25%</td>
</tr>
</tbody>
</table>

6. Conclusions and Future Work

A new graduate level course entitled MECH/AREC 581 Sustainable Technology Entrepreneurship for Scientists and Engineers (STESE) has been developed and is described herein. The course, which was supported by a grant from the NCIIA, was developed and delivered by the Colleges of Engineering, Business and Agricultural Sciences at Colorado State University. The goals of the STESE course were to instill an entrepreneurial mindset and global/sustainable perspective among engineering/science students, and to provide technical expertise to student teams within the GSSE program.

The motivation behind the first goal of STESE was to address an identified deficiency of adequate entrepreneurship training opportunities for graduate students within engineering and agricultural sciences at CSU. Numerous startup companies had spun out of these colleges in recent years by graduate students with good ideas but with little formal business training. And, while a wealth of business expertise and curriculum existed within the GSSE program and the College of Business at large, it was difficult for engineering and science graduate students to take advantage of these resources given the intensity of the graduate curricula in their own technical disciplines. The motivation behind the second goal was to address a critical shortage of engineering/science acumen within the GSSE teams that were engaged in sustainable enterprises in developing countries. The latter need was satisfied by assigning engineering and science students from the STESE course directly to the GSSE teams.
In its first offering, the STESE course was cross listed between the Colleges of Engineering and Agricultural Sciences, which yielded a total enrollment of 40 students among 6 different majors. The STESE course utilized condensed material from multiple offerings within the College of Business but did not require any prerequisites. The course was team taught by faculty from three departments (Management, Mechanical Engineering, Agricultural Resource Economics) in a weekly format that included lecture, project based learning and guest speakers. The 16-week semester was divided into four general topic areas: the entrepreneurial mindset, product realization, opportunities at the base of the pyramid and new venture management. Student evaluations from the first offering of the STESE course strongly suggest that the students gained valuable exposure to commercialization opportunities for their graduate research along with the recognition of the potential opportunities at the base of the global economic period. The slate of guest speakers was overwhelmingly evaluated as the most valuable aspect of the course. The project component of the course was generally viewed less favorably.

The second offering of the STESE course is scheduled for the Spring 2011 semester. Based on feedback from the students and reflection among the instructors, we have identified the following areas for improvement:

- Improving the interface with the GSSE program,
- Using the course as a means of harvesting technology from university research labs,
- Modifying the choice of textbook and doing a better job of reinforcing the material in the textbook.

Each of these identified areas of improvement will be briefly discussed here.

Based on the varying levels of success of the GSSE related projects, the STESE faculty team must interface more closely with students and faculty in the GSSE program. The interface has to improve on both the “in flow” and “out flow” of projects from the STESE course. On the “in flow” side, a better job needs to be done in vetting the GSSE projects for their need and readiness for a STESE team. In some cases the GSSE projects were too far along in their development and in other cases the GSSE projects were premature. In terms of “out flow”, several promising projects have come out of the STESE course, but a formal means of transitioning these projects into the GSSE has yet to be developed.

Based on student feedback and faculty reflection, several of the student generated projects were contrived rather than realistic. The contrived nature of the projects was compounded by the fact that it was very difficult, if not impossible, in most cases to generate customer needs data from the developing economy for which the opportunity was envisioned. Moreover, a substantial subset of students enrolled in the course at the suggestion of their graduate research advisor as a possible means to learn how to commercialize the intellectual property developed in their lab. Accordingly, in the second offering of the STESE course, we plan to develop a better means of harvesting intellectual property from university research labs. In the year since the first offering of the course, the faculty team has been contacted by numerous colleagues at CSU who have IP for which they would like to develop an opportunity assessment. We have advised those faculty members to recommend the course to their grad students and give those students the opportunity to work on the IP from their lab for their project. Consistent with this theme, we have lined up a slate of guest speakers that includes five faculty members who are engaged in startup enterprises that originated with university IP (Envirofit, Solix, Abound Solar, Prieto Battery, OptiEnz Sensors).
Lastly, the textbook (and to be fair, the way we used the textbook) was not effective. In the upcoming offering, we have chosen the textbook Technology Ventures by Byers, Dorf and Nelson [23]. This textbook is organized into four major areas: Venture Opportunity/Concept/Strategy, Venture Formation/Planning, Detailed Functional Planning, and Financing/Building the Venture. These areas will provide a consistent backdrop for the students as they work through their project and will also provide students with an introduction to the skills needed to commercialize university IP. As important as the choice of the new textbook, the course outline for the second offering of STESE will be much more consistent with the organization of the text book and we will utilize some of the case studies in the book to reinforce the key topics of the course.

Acknowledgments

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