

Product Realization for Global Opportunities: Learning Collaborative Design in an International Setting*

MATTHEW M. MEHALIK, MICHAEL LOVELL, LARRY SHUMAN

Department of Industrial Engineering, University of Pittsburgh, Pittsburgh, PA 15261, USA.

E-mail: mmehalik@pitt.edu, mlovell@pitt.edu, shuman@pitt.edu.

This paper discusses lessons learned from an innovative course—Product Realization for Global Opportunities—first offered in Spring 2007 at the University of Pittsburgh. Its purpose was to further infuse both sustainability and product realization into the undergraduate engineering curriculum. We have done this by creating a unique product realization course in which E-teams of students from University of Pittsburgh and the University at Campinas (UNICAMP) in Brazil attempt to develop products for sustainable human development. In particular, the course addresses the product realization process in the context of sustainability for the developing world. In doing this, we have taken advantage of the School of Engineering's rapidly expanding interest in sustainability led by the Mascaro Sustainability Initiative (MSI), a growing relationship with UNICAMP, and close involvement from the University's International Business Center and the Center for Latin American Studies (both Department of Education Title VI National Resource Centers). Further, students use our Swanson Institute for Product Innovation to develop prototypes. Course development was supported by a programme grant from the National Collegiate Inventors and Innovators Alliance (NCIIA). This paper presents findings from surveys conducted at the end of the course including an entrepreneurship questionnaire developed by the National Collegiate Inventors and Innovators Alliance (NCIIA). The course produced significant increases in students' self-perceptions of skills needed to become an entrepreneur and in financial dimensions of entrepreneurship as well as idea generation, product pricing, and intellectual property concerns.

Keywords: Product realization; international programmes; design for human development; sustainable design; global issues in engineering

COURSE GOALS AND CONTEXT

UNDERGRADUATE ENGINEERING AND BUSINESS STUDENTS in ENGR 1610: Product Realization for Global Opportunities, during the Spring Term 2007, completed five projects designed to improve the quality of life for Brazilians living in urban, public housing. The course, which was partially funded by grants from the NCIIA and the Mascaro Sustainability Initiative, focused specifically on designing products that could improve housing, living conditions and/or personal security for Brazilians living in public housing.

The purpose of this course was to promote effective, virtual and in-person international student collaboration in the undergraduate engineering and business design curricula using the theme of sustainable product design. The goal was to create a course in which University of Pittsburgh engineering and business students design, construct prototypes and create business plans for new technologies, using sustainability as a framework, and work directly with students from the University of Campinas in Brazil. That is, this

course would address the product realization process in the context of sustainability, especially for the developing world, in a collaborative fashion, rather than an over-the-wall fashion. In doing this, we have taken advantage of the School of Engineering's rapidly expanding interest in sustainability led by the Mascaro Sustainability Initiative (MSI), a growing relationship with UNICAMP, and close involvement from the University's International Business Center and the Center for Latin American Studies (CLAS); both of these are Department of Education Title VI National Resource Centers. The CLAS provided vital language and cultural preparation, as well as guiding the interaction of students. Students used our Swanson Institute for Product Innovation, which has had a long history of involvement with the NCIIA, including the NCIIA RAPID Network, for prototype development.

Why sustainability? Clearly, engineering students must understand that the planet's natural resources are limited and that the next generation's products and processes must be designed with sustainability deeply embedded. Further, issues such as sustainable water and green construction, the MSI's major focus areas, impact large portions

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of both the developing and developed worlds. As a result, engineers must include sustainability as a fundamental design constraint, both for the well-being of future generations and for the US to remain economically competitive. According to Thomas Friedman [1], 'green technology is emerging as the most important industry of the 21st century'. He warns that [if nothing is done]: 'Wait a decade, when we'll have to import our green technology from Beijing, just as we have to import hybrid motors today from Japan'.

The University of Pittsburgh's relationship with UNICAMP [2] currently includes an NSF Integrative Graduate Education and Research Training (IGERT) grant whose objectives include training a cadre of graduate engineers to create sustainable products and processes, especially for the construction and water collection/purification industries. The Product Realization for Global Opportunities course was the first to extend the collaborative relationship with UNICAMP to the undergraduate level. This project builds off of a growing relationship with UNICAMP faculty, particularly Dr Vanessa Gomes da Silva and Dr Doris Kowaltowski, who specialize in sustainable design solutions, particularly in civil engineering and construction, and architectural applications. Now an NSF IRES grant that enables undergraduates to conduct research in Brazil and a FIPSE-CAPES grant (Department of Education) awarded that will enable Brazilian and US undergraduates to study in each others' countries have been received.

Engineering and business education must adapt to the dynamics of a highly complex, global economy in order to discover how to solve difficult, interdisciplinary problems through design and innovation. Students and faculty must learn to work cross-culturally, build international networks of collaboration, and develop products that will meet the demands of the developing world. Prahalad [3] has proposed that the needs of developing nations serve as sources of opportunity for innovation, if the appropriate collaborative networks can be fostered. Kim and Mauborgne [4] note that the highest yielding sources of value in innovation occur when networks look beyond established markets. Virtual networks for collaboration provide opportunities to achieve these high yields, if teams are structured to permit functional interaction, a challenge of this course.

In addition, by working with the University's International Business Center and its College of Business Administration, we have included business students as part of the product development teams. Hence, business and engineering students from Pitt and engineering and architectural students from UNICAMP are able to work together to design products that address sustainability needs. To date, these teams have functioned primarily in virtual modes, utilizing the Internet and video conferencing; however, the course also featured a one-week trip in early March 2007,

during Pitt's Spring Break. This visit permitted Pitt students to interact directly with the UNICAMP team members and observe the actual setting in which the products under development would be used.

The instruction in sustainable development was enhanced through the use of case studies [5, 6, 7]; background readings and guest speakers. Students received basic cultural and language preparation with assistance from the University's Center for Latin American Studies and its active study abroad programme.

This course joins a growing list of efforts in engineering education that prepare engineering students for the more globalized economy [8, 9, 10], providing them with the technological tools to better meet the challenges of sustainable engineering [11, 12, 13], and to prepare them for working with people in different cultures on the broad challenges [14] perceived to be vital for creating a sustainable world.

COURSE OBJECTIVES AND STRUCTURE

Our objectives were to:

- Provide an opportunity for students to work cross-culturally, in diverse teams (business and engineering) in international settings (University of Pittsburgh and the University at Campinas, Brazil) both in-person and in virtual collaborative environments;
- Develop viable, marketable products that address sustainable development needs;
- Gain knowledge and skills in product realization and project management, including the ability to transfer a work in progress to other team members of engineering/business students;
- Understand the impact of engineering solutions in a global and societal context and achieve insight into professional and ethical responsibilities.

The overall E-teams' assignment was to develop a sustainable product from concept to prototype to business plan. In doing this, students learned about needs assessment, problem definition, market research and analysis, preliminary design, manufacturability, prototyping and production planning. Each team had a \$1200 budget to produce functional prototypes, although most teams spent much less than this amount.

Students were recruited for the course by circulating a flyer to all engineering undergraduates and to undergraduate business students. This flyer highlighted the above objectives and the stipend that would reduce the cost of travelling to Brazil for spring break. The flyer was circulated during the course enrolment period in November 2006 through an engineering school-wide undergraduate email distribution list. Because of the significant amount of technological learning involved in creating physical embodiments of designs, this

course would count as technical electives for all engineering degree programmes. The course also counted as a technical elective for marketing majors in the College of Business Administration. This eligibility was an attractive feature. The course was targeted for third and fourth year undergraduates. Initial interest was high. The instructor kept a waiting list of students for overflows in registration. The instructor expanded the initial enrolment to 20 students instead of the originally planned 15 students to accommodate the large response. Eventually, 17 students completed the course in its entirety.

Recruitment was also helped through existing collaborations in international education at the University of Pittsburgh. The University's business-engineering Plus 3 Study Abroad Program for rising sophomores had received the Institute of International Education's 2005 Heiskall Award for innovation in international education (see <http://www.abroad.pitt.edu/plus3/index.html>). A pool of students had visited Brazil as part of the Plus 3 programme. The product realization course filled the requests of many students who had enjoyed the freshman-level Plus 3 travel experience and wished to follow-up with more in-depth, technical content-oriented international educational experiences. Students were also strongly encouraged to select one of the University's rich offerings in Latin American studies as their humanities/social science electives.

Dr Mehalik travelled to Brazil in December 2006 to make arrangements for the March visit to Brazil. UNICAMP and University of Pittsburgh faculty jointly developed a set of possible areas for students to research as a first step in the product design process during this December 2006 visit:

- Improve the safety, reliability, and energy usage of hot water for showering;
- Improve the quality of lighting in homes while reducing energy consumption;
- Improve the quality of construction methods and materials for self-built homes;
- Supply drinking water in a manner that reduces the need for placing water boxes (i.e. individualized storage tanks) on the roofs of homes;
- Meet personal security needs without resorting to the current practice of enclosing homes and properties with high block walls topped with razor wire, broken glass, or some other deterrent.

The visit to Brazil was also planned in a way such that students would also be able to experience Brazilian culture. Excursions were arranged to:

- Housing areas of different income levels in and around Campinas;
- The Serra do Mar Atlantic Forest, a southeastern Brazil rainforest rich in biodiversity;
- Paraty, a historic, well-preserved colonial town on the Brazilian coast between Santos and Rio de Janeiro;

- Rio de Janeiro's Ipanema beach and some of its famous landmarks, including the Corcovado mountain, and the Pão de Açúcar.

When the course began in January, students were assigned to teams of three or four, depending on their interests, subject to distributing the ten engineering and eight business students evenly across the five teams. The instructor emphasized how each topic area involved issues of economic, social and environmental sustainability. Finding a workable balance among these factors was crucial to creating a successful product and for providing market choices that would contribute to sustainable development.

The instruction in sustainable development was enhanced by utilizing case studies [3, 6, 7], background readings and guest speakers. Students also received basic cultural and language preparation with assistance from the University's Center for Latin American Studies; the University's study abroad programme provided an orientation for international travel and ensured that each student had the necessary health insurance.

Students spent three weeks on background readings and exercises that addressed product design, sustainable development and the history, cultures and languages of Brazil. They used an iterative process to choose, evaluate and refine their product ideas that included extensive information on Brazil using electronic databases that described markets, consumer choices and industry trends. Students shared their initial design ideas with faculty and students from UNICAMP via video-conferencing and online forums when the UNICAMP term began in late February. Each of the five teams created a preliminary design concept from these activities.

Students kept design logs for all of their design activities. They also maintained electronic design logs of their electronic communications, drawings, and design ideas. These electronic artifacts were the main avenues of communication between UNICAMP and Pitt students. In addition, students conducted their design activities in a special design laboratory, which recorded the design processes in video and audio format (with the students' consent and according to IRB guidelines).

The teams then refined their designs during a week-long visit to Brazil in early March. Students shared detailed design plans and market assessment ideas with UNICAMP students, faculty, and consultants during this visit. Several teams were able to successfully survey potential consumers during visits to several Brazilian towns. The student teams revised their design ideas based on this firsthand, onsite experience with local residents and UNICAMP students, and faculty.

After returning to Pittsburgh, the student teams then focused on turning their revised, validated preliminary design concepts into detailed designs. This effort involved specifying the exact geometry, materials and assembly methods needed to actually

create the product. The students created CAD drawings based upon their design specifications, and from these drawings they created both functional and illustrative prototypes using stereolithographic (SLA) equipment in the RAPID laboratory at the University of Pittsburgh. The teams also specified the materials that would be needed to create their final designs. From this list of materials, students researched the cost of manufacturing their designs. They combined this information along with their market database searches, surveys, and input from UNICAMP students and faculty in order to create preliminary sales forecasts, breakeven analyses and preliminary balance sheets for their business plans.

At the end of the semester, students presented their ideas to a panel of faculty and company experts (from both Pitt and UNICAMP) through the use of video capabilities. Students prepared posters for the design symposium at which they presented their business plans to the class and the panel. Food is provided at the event, and students are encouraged to invite their family members, friends, or other people who would be interested in the final outcome of the semester-long design effort.

The teams that were judged to be the most promising were invited to convert their business plans into E-team grant applications for the NCIIA bi-yearly competition. Winners of that competition would receive grants that provide up to US\$20,000 to the student teams in order to move their products into the marketplace. The University of Pittsburgh has successfully created several startup companies using this method in the past; however, the successes occurred in US domestic markets. This course provided the foundation for extending the ability to create businesses that have access to international markets, involving international collaboration. Two of the five teams submitted applications for the NCIIA grant based on the encouragement of the symposium judges. Unfortunately, neither was funded, due in large part to their relatively simple concept that was more low tech than high tech (as a result of our emphasis on innovation rather than technology).

The course also takes advantage of UNICAMP's calendar with a Fall term from March into July, enabling the UNICAMP students to span Pitt's Spring and Summer terms. Product ideas that were not ready for submission to the NCIIA could be handed off to UNICAMP students, with Pitt students who were enrolled in the summer section of the Product Realization Course acting as collaborators using electronic communication. This transition was piloted for one of the project with IRES students.

PROJECT DESCRIPTIONS

The five products that the student teams created in the Spring 2007 are described below. Each

product was innovative in terms of meeting a documented need in Brazil, in terms of addressing a sustainable development goal, and in terms of having a significant impact on real Brazilian consumer markets:

Electric shower connector

In Brazil, a low cost shower uses a head with an electric heating element that heats water upon contact. This team discovered that many people were shocked while showering due to bare, exposed wires located at the shower head's connection. Lacking electrical expertise and materials for waterproofing, people typically connected electric shower heads in ways that compromised safety. (The remedy of choice was to wear rubber shower shoes to prevent these electrical shocks.) In addition, electric shower heads needed to be frequently replaced when the heating elements broke. In many instances, people simply uncoiled portions of any remaining heating element to complete a circuit, further producing unsafe operating conditions that often resulted in the shower head catching on fire.

Because of their very low initial purchase costs (about US\$15.00 or about R\$30), electric shower heads are popular in Brazil. The design team decided not to redesign the shower heads themselves because of saturated market conditions and relatively low purchase price. Instead, they decided to design an inexpensive, intuitive device to connect the shower head to the household wiring so that the installation was quick, easy, waterproof, and safe; i.e., they wanted to improve product safety and reduce the potential for product failure (See Fig. 1). The device consists of a plastic cylinder with three holes on both ends into which the wall and shower head wires are inserted to complete the connection. The wires are held in place with tapered rubber keys in slots that are locked with a hand-turned plastic nut. The business plan for the product involves bundling the device with the shower head. The symposium judges recommended this team apply for an E-team grant for this product.

Light bulb energy monitor

One of the most economic ways for both consumers and Brazilian utility companies to reduce energy consumption involves having customers switch to more efficient light bulbs. Compact fluorescent bulbs are widely available in Brazil,



Fig. 1. 'Safe' electric shower head.

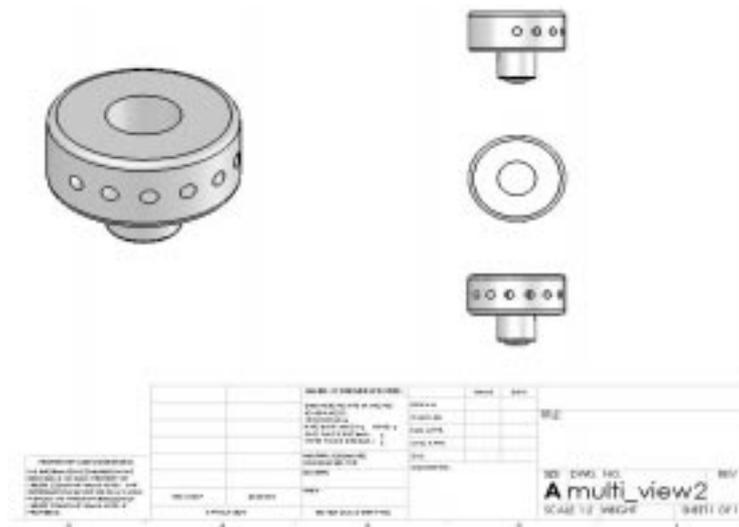


Fig. 2. 'Musical' light bulb energy monitor.

although, much like in the US, consumers tend to not choose them because the retail price is higher than that for incandescent bulbs, despite long term cost savings stemming from lower electric usage. This student team devised a small, very inexpensive electronic device that utility companies would provide to consumers in order to encourage them to examine their light bulb energy usage. The device (Fig. 2) screws into a typical light socket, and then the bulb is screwed into the device. Once both the device and bulb are installed, the device uses several LED lights and a computer chip to create a display that shows the energy efficiency of that bulb. The scale of the LED lights corresponds to a chart that estimates the long term costs of using such a bulb. The device also plays music to highlight its 'approval' of energy efficient bulbs and its 'disapproval' of inefficient ones. The symposium judges recommended this team apply for an e-team grant for this product.

Mortar template

Many Brazilians create their own homes from such materials as block and mortar, purchased from corner hardware stores. Many people lack masonry training and craftsmanship skills, and this often results in crooked, unsafe walls, with a lot of wasted construction materials, such as extra mortar in between blocks. This team designed a one-piece, heavy duty plastic device that holds the proper amount of mortar for a short course of block (Fig. 3). The device, once filled with mortar, is placed on the top course of block and removed. The new course of block is applied and pressed into shape. The device ensures that the joint is neat, straight, and without extra mortar. The device would be bundled with the sale of ready mix mortar at local hardware stores.

Rainwater purifier

This device consists of an 11-litre boiler that purifies rainwater. Rainwater would be poured

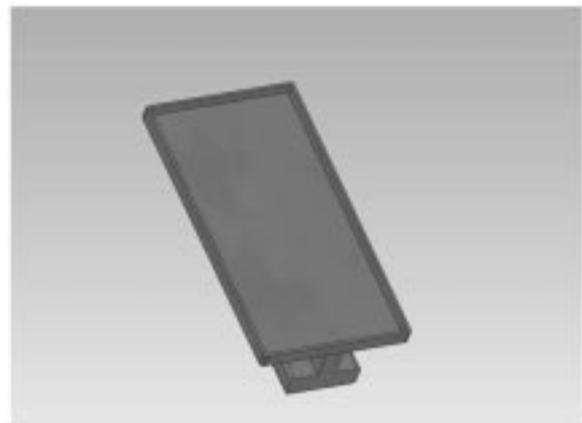


Fig. 3. 'Just right' mortar template.

into the top of the device, which contains a carbon-activated filter to collect sediment and other chemicals that might have been dissolved in the rainwater. The filter is also capable of removing most microscopic organisms. The water flows into a pear-shaped container that uses an electric heating element to boil the water in order to destroy living organisms. The final stage involves adding a very small amount of chlorine tablets (a state mandated requirement) to complete the purification process. This device reduces the need for having to use city water, which is often unreliable and poorly treated.

Personal security device

This product consists of a combination alarm, light, and pepper spray device that can be used if attacked. This team's surveys revealed that not all younger Brazilians desired to continue to embrace the current cultural convention of simply surrendering to an attacker. The team also discovered that many of these same people did not want to possess a handgun for their safety. This personal safety device is designed to increase the potential

cost to an attacker by spraying the attacker with pepper spray. Such devices are not used at all in Brazil currently, and so this team saw an opportunity to introduce it. Their plan was to offer this pepper spray/light/alarm device in a very inexpensive and refillable form. The device has a removable container so that new cartridges of pepper spray can be easily inserted to replace old ones. This group plans to market the device through the interaction of NGOs that wish to reduce the power of favela gang leaders.

POST-TRIP SURVEY

Students completed an open-ended questionnaire in the next class after returning from the trip to Brazil. The questionnaire was designed to capture information related to their experiences and what they believed they learned as a result of the experience. Each of the questions follows, with a summary of the most common responses. For each question, however, it was possible for the student responses to fall into more than one category. The questions with corresponding frequencies of different student responses are included in Appendix A.

In terms of previous travel experience, the group was nearly split between those who had extensive travel experience and those who have very little. Of the 17 students, the largest group ($n = 7$) had made more than four previous trips abroad or had studied abroad at least one semester. Two students had traveled about at least three times before; six students were making their second trip abroad, the majority of whom had made their first trip abroad as freshmen in the Pitt Plus 3 programme mentioned earlier. Only two students were making their first trip outside of the US. Presumably, this weighting towards having a more experienced group provided more ability to focus on design tasks and interaction than would have been possible with a group of inexperienced travelers.

When the students visited the various housing sites during the trip, the most common take-away was the insight gained into how to improve their existing product ideas ($n = 8$). For some students ($n = 4$), the visit resulted in the need for them to reframe their project ideas. The visits to the housing sites also provided insight into the physical space and the lifestyles of people living in public housing. These outcomes appear to be in accord with the intentions behind those site visits.

Students also visited a Natura factory, a cosmetics company that specializes in sustainable manufacturing processes, and hardware stores and markets where housing products could be sold. From these visits, students gained insight into how their products could be priced, marketed ($n = 10$), benchmarked ($n = 7$), and produced ($n = 2$). In addition, the Natura factory appeared to provide

an ideal model for how products could be manufactured using a sustainability model ($n = 10$).

Students were asked about what concepts or practices related to sustainability they learned or observed while on the trip. The responses tended to fall on two opposing sides of comparing Brazil and the US. On the one hand, the most common response ($n = 7$) was how Brazil was ahead of the US in sustainability practices. Others were how extensive they observed recycling of materials ($n = 6$) and the availability of alternative fuels ($n = 2$) in Brazilian society. On the other hand, students noted the need to improve living standards ($n = 5$), the overall lack of planning in housing construction ($n = 5$) and the lack of energy efficiency ($n = 3$).

More than half of the students ($n = 10$) reported that their interactions with students and faculty at UNICAMP helped them gain more insight into Brazilian customer needs, culture, and preferences. Nearly half ($n = 8$) needed to reframe or redirect their original project ideas after meeting with the UNICAMP faculty and students.

In terms of what the most important concept or idea the students learned while on this trip, the students rarely mentioned sustainability concepts or human development concepts. Instead, students mentioned Brazilian culture ($n = 4$), the breadth of the world's culture ($n = 4$) and the need to respect other cultural ideas ($n = 3$). These responses may indicate that the trip's major impact is a cultural experience folded into a design task.

When asked how the travel experience exceeded their expectations, the students reported that they were surprised by the overall positive quality of the travel experience ($n = 12$), the friendliness of Brazilians ($n = 7$), and the beauty of Brazil as a country ($n = 6$). Other responses included how comfortable the housing and accommodations were ($n = 2$) and the quality of the food ($n = 2$).

When asked how the trip did not meet their expectations, the students most frequently mentioned problems with airline travel ($n = 7$), the desire for more free time ($n = 6$), and that the schedule was too busy ($n = 2$).

Finally, students voiced several recommendations in terms of improving the travel experience in future years. The most frequent response was using a better airline ($n = 6$). This was not a surprising result, given the fact that half of the class had their trip delayed by two days as a result of airline flight cancellations due to weather problems and overbooking. Students requested more language training ($n = 5$), more interaction with Brazilian students ($n = 3$), and communication improvements with the travel agency ($n = 3$).

ENTREPRENEURSHIP SURVEY

Students also completed a pre-post survey designed for students to self-rate their levels of

abilities in several dimensions of entrepreneurial categories. This survey is being created and piloted by the National Collegiate Inventors and Innovators Alliance, and it includes 105 questions for which students rated their abilities for these questions as: NONE (Never heard of it), LOW (Heard of but not sure what it means), MODERATE (Can explain it partially), HIGH (Can explain in depth but not sure how to apply it), or VERY HIGH (Can explain in depth and can apply it). Each of these items corresponds to a five point numeric score of 1 = NONE to 5 = VERY HIGH. The 105 questions were grouped to create aggregate measures of the following areas of entrepreneurship: 'Becoming and Being an Entrepreneur' (37 questions), 'Finance and Accounting' (27 questions), 'People and Human Resources' (6 questions), 'Sales and Marketing' (15 questions), 'Product Ideation and Development' (6 questions), 'Product Pricing' (3 questions), and 'Intellectual Property' (11 questions). For each category, each question contributed an equal amount in the average score computed for each of the areas listed [15].

Students were administered this questionnaire during the first week of the course in January 2007 (as a pretest) and during the last week of class in April 2007 (as a posttest). Of the 17 students who completed the entire course 15 submitted questionnaires that could be processed to compute pre-post differences in three of the aggregated categories (Becoming an Entrepreneur, Finance, Human Resources and Intellectual Property), and of those 15, one student did not answer questions in the remaining categories (Sales & Marketing, Product Ideation and Pricing).

The assessment instrument revealed that there were statistically significant gains in students' perceptions of their own learning in four of the seven aggregate categories. For 'Becoming and Being an Entrepreneur', student ratings gained 0.49 points from $M = 3.55$ ($sd = 0.45$, $n = 15$) to $M = 4.03$ ($sd = 0.49$, $n = 15$). These gains are significant at a 95 per cent confidence interval ($t = 2.79$, $p < 0.01$) with an effect size of 0.47. The results point to a shift from the MODERATE to HIGH level of perceived ability in this concentration of entrepreneurial abilities.

For 'Finance and Accounting', the ratings gained 0.46 from $M = 3.38$ ($sd = 0.46$, $n = 15$) to $M = 3.84$ ($sd = 0.56$, $n = 15$). These results were statistically significant ($t = 2.46$, $p < 0.03$) with an effect size of 0.42. These shifts occurred within the MODERATE to HIGH ranges of ability on the 5-point scale.

For 'Product Ideation and Development', student ratings increased 0.60 from $M = 4.25$ ($sd = 0.64$, $n = 14$) to $M = 4.85$ ($sd = 0.22$, $n = 14$). The results were statistically significant ($t = 3.32$, $p < 0.01$) with an effect size of 0.55. The shifts occurred from the HIGH to VERY HIGH rating of ability in this particular area.

Finally, for 'Intellectual Property', ratings in-

creased 0.75 from $M = 3.05$ ($sd = 0.59$, $n = 15$) to $M = 3.79$ ($sd = 0.72$, $n = 15$). The results were again statistically significant ($t = 3.08$, $p < 0.01$) with an effect size of 0.47. These shifts occurred from the MODERATE to the HIGH ranges on the scale.

It should be pointed out that the mean scores increased from pre to post for all of the remaining areas; however these increases did not correspond to statistically significant increases at the 95 per cent confidence interval.

The results of this survey can be interpreted to highlight that significant perceptions of learning did occur in the class, particularly in the dimensions of the course that received the most emphasis. Students did spend much of their time generating new ideas for their products and then doing a significant amount of research on trying to understand how such a product could work financially in a Brazilian marketplace. Students were able to talk with several students, faculty, and other professionals domestically and in Brazil to help them come up with their ideas and to find out where peoples' needs and market opportunities exist. The course lectures emphasized the product development process, financial analysis, and intellectual property options for student ideas. All of these areas showed significant increases in ratings on the student survey.

Most of items that were not statistically significant tended to fall towards the very end of the course, when issues such as pricing, marketing, and sales were presented. The two course instructors were both from the School of engineering, and perhaps this outcome reflects the lower degree of expertise in these areas on the part of the faculty. This suggests that a College of Business co-instructor might improve outcomes in these areas.

An interesting and surprising finding is that there were no statistically significant increases in the ratings in the 'Human Resources' dimension of the survey. This result is surprising given the large degree of emphasis on teamwork and international collaboration that was built into the course. This result suggests the need to follow-up on how students perceive their interactions with others in the design process and how this aspect needs to be improved—this is especially critical given the international collaboration dimension of this class.

LESSONS LEARNED AND FUTURE STEPS

Overall, students did successfully create innovative, appropriate prototype products and business plans for Brazilian markets in an internationally collaborative design setting. Students were able to work from vague initial design concepts, conduct market research in order to generate preliminary design requirements and alternative design concepts. The students successfully interacted with UNICAMP students and faculty in face-to-face and virtual environments in order to refine conceptions of needs and market potential,

product design ideas, and to check the cultural appropriateness of the design ideas. They were able to advance their ideas into working prototype form, estimate the cost of manufacturing them, and then provide realistic plans for turning the products into a business. All five teams were able to complete this task. It should be noted that this is not always the case for the U.S.-only version of the Pitt product realization course. By these measures, this course has met many of the goals for its first offering. In addition, students were able to have an enjoyable and informative cultural experience during the week-long visit to Brazil over Pitt's spring break.

The survey results provide insight into several aspects of the design of the in-country portion of the course. Overall, students learned several aspects of sustainable design as part of the site visits and interaction with students and faculty. However, students expressed wanting to increase the amount of time for interacting with students from Brazil. Because of the airline delays, students missed almost 50 percent of the face-to-face time that was scheduled for the Brazilian students and faculty to interact, plan, and share design ideas. Students were able to interact during many of the bus trips, site visits, and informal gatherings; however, these interactions provided less intense and with less focus on project design.

Because this was the pilot version of the course, the overall level of interaction between students and faculty at both institutions can be improved. First and foremost, UNICAMP will be offering a design course that will more directly coincide with the goals of this product realization course. This past spring involved mainly students who were enrolled in independent studies at UNICAMP for the interaction on the design tasks. Having

the course at UNICAMP will provide more of a formal structure and better time coordination, both of which will improve the course. In addition, students expressed an interest to increase the amount of language training available before the in-country portion of the course takes place.

The course is in the process of being evaluated more extensively with several surveys which track more of the conceptual learning that occurred in terms of the entrepreneurial mindset and product development process are being processed.

Finally, the existing Minor in Product Realization is able to sustain itself through the support of local companies who provide product development ideas. Because of this local focus, to this point such companies do not provide support for international collaboration. Through our interaction with faculty at UNICAMP, this course has permitted us to establish seek support from Brazilian companies. One such company is the construction firm Rossi Construction, which has interests in sustainable construction materials. This course has provided the necessary bridge so that other such relationships can be built so that these firms will provide support for international collaboration for product creation. We are in the process of soliciting additional support from local foundations in Pittsburgh with interest in sustainability for the course in order to ensure its continuation.

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15. Copies of the NCIIA Entrepreneurship Survey can be requested by contacting the NCIIA at www.nciia.org

APPENDIX A

Survey results

How much previous international travel experience did you have before departing?

Amount of previous travel experience	Frequency
First time abroad	2
2 nd time abroad	6
3 rd or 4 th time	2
Widely travelled/studied abroad	7

How did the visits to various housing sites help you shape your design project?

Housing site visit impact	Frequency
More depth to current project idea	8
Re-frame project	4
Insight into physical space	4
Insight into lifestyle	4
Other	2

How did the visits to various factories and stores help you shape your design project?

Factory/store site visit	Frequency
Insight into pricing and market	10
Provide ideal model for sustainable design	10
Product benchmarking	7
Insight into production methods	2
Other	2

What concepts or practices related to sustainability did you learn or observe on the visit to Brazil?

Sustainability concepts	Frequency
Brazil ahead of US in sustainability practices	7
Extensive amount of recycling among people	6
Extensive need to improve Brazilian standard of living	5
Lack of planning in housing construction	5
Lack of energy efficiency	3
Availability of alt. fuels	2
Other (housing)	2
Other (general)	2

How did discussions with UNICAMP faculty and students shape your project?

UNICAMP faculty/student	Frequency
More insight into understanding Brazilian customer needs	10
Need to re-frame/redirect current project idea	8
Other	2

What was the most important concept or idea you learned while abroad?

Important idea learned	Frequency
Overall experience/Brazilian culture	4
Breadth of world's culture	4
Need to respect other cultural ideas	4
Other	3

In which ways did the travel experience exceed your expectations for the trip?

Ways exceed expectations	Frequency
Overall positive quality of experience	12
Friendliness of Brazilians	7
Beauty of Brazil	6
Quality of housing	2
Good food	2
Other	2

Ways not meet expectations	Frequency
Airline issues	7
Want more free time	6
Schedule too busy	2
Other	1

What are your recommendations for improving the programme next year?

Ways to improve programme	Frequency
Better airline	6
More language training	5
More interaction with Brazilian students	3
Travel agent logistics and communication	3
More free time	1

Matthew Mehalik is a Visiting Assistant Professor in Industrial Engineering and a Research Associate at Pitt's Learning Research and Development Center. His interests involve the intersection of engineering and policy in complex systems, particularly during innovation and design.

Michael R. Lovell is Associate Dean for Research and Associate Professor of Industrial Engineering, the Executive Director of the Swanson Center for Product Innovation and Director of the Swanson Institute for Technical Excellence.

Larry J. Shuman is Senior Associate Dean for Academic Affairs and Professor of Industrial Engineering. His research focuses on improving the engineering educational experience, the assessment of engineering education, and the ethical behaviour of engineers. He is the founding editor of *Advances in Engineering Education*.