# International senior design for mechanical engineering students

**Tammy Haut Donahue**
Michigan Technological University, Houghton, USA
thdonahu@mtu.edu

**Sheryl Sorby**
The Ohio State University, Columbus, Ohio
sheryl@mtu.edu

***Abstract**: In recent years, many international opportunities for engineering students have been developed through organizations such as Engineers Without Borders (EWB) or Engineers for a Sustainable World (ESW). While these opportunities appeal to young people's sense of responsibility for making a positive difference in the world, most projects are aimed at infrastructure enhancement or development and, as such, are geared towards students majoring in civil, environmental, or geological engineering. The infrastructure projects typically have need for one or two engineers outside of these disciplines; however, a mechanical engineering student working on developing a water purification system for a remote village will likely play an ancillary role in the design and construction of a facility such as this. Further, many senior design projects in mechanical engineering at Michigan Tech are centered around building a faster racecar or building a cleaner engine—projects which have little to no appeal for many young women. In September of 2009, the decision was made to offer a new type of design project, a project with a humanitarian focus and an international component, for senior mechanical engineering students. The new international design program would include options for the design of assistive devices for handicapped children in India (India has the highest rate of birth defects of any nation in the world). In preparation for this international senior design option, two faculty from the mechanical engineering department traveled to India in April of 2009 to meet with various individuals and make plans for the coming year. The international senior design option was implemented in the 2010-11 academic year, culminating in a faculty-led student trip to India to test the devices and to identify projects for the following academic year. This paper describes the program, lessons learned, funding challenges, and outcomes from the development of this humanitarian engineering program.*

## Introduction

In September of 2009, the decision was made to offer a new type of design project, a project with a humanitarian focus and an international component, for senior mechanical engineering students. The new international design program would include a project centered on the design of assistive devices for handicapped children in India. India, the second most populated country in the world, representing about one sixth of the world's total population, has approximately two thirds of its population living in

Proceedings of the 2011 AAEE Conf., Fremantle, Western Australia, Copyright © Haut Donahue and Sorby, 2011

poverty. India has the largest concentration of poor in the world with forty-two percent of Indian citizens living below the World Bank's International Poverty Line of making US$1.25 or less per day. Many live without even the basic necessities of western culture, such as clean water and weatherproof shelter. Due to living conditions, home birth, and lack of vaccinations, the incidence of polio, spina bifida, cerebral palsy, and other spastic conditions remains high in low and no income families in India. Eighty percent of cerebral palsy is spastic, in which most of those affected suffer from one to two lower limbs being affected. Those lower limbs that are affected are weak, and the ability to walk without an assistive device is challenging. Furthermore, India is one of four countries in the world that has not eradicated polio. In about one percent of the cases of polio, the virus will enter the central nervous system and destroy motor neurons leading to muscle weakness and acute flaccid paralysis (AFP). Spina bifida, a developmental birth defect, leads to the weakening of lower limbs depending upon which part of the spine is affected. Clearly, there is a dire need for low-cost assistive devices in India.

That being the global problem of interest, there is a local problem of interest as well. Engineers often lack international experience and the ability to think globally. The curriculum is typically too "full" to enable study abroad experiences or to allow for in-depth study of other cultures. The lack of a global focus in the undergraduate curricula is to the detriment of the field in that engineers typically work in global companies and are required to interact with colleagues from across the world. The proposed initiative addressed this through having teams of engineering students at Michigan Technological University design, prototype, and develop manufacturing plans for low-cost assistive devices that meet the constraints of Indian culture while meeting the processes, tools and skills constraints associated with the target Indian workforce. This project represents the type of situated learning experience advocated by Lave & Wenger (1990) where students solve problems in the culture and context where they occur. Brown, Collins & Duguid (1989) further theorize about the concept of cognitive apprenticeship where students develop cognitive tools in an authentic setting.

In April 2010, to prepare for this international senior design option, two faculty from the Mechanical Engineering Department (Dr. Haut Donahue and Dr. Sorby) visited the greater New Delhi area to learn about problems with currently available assistive devices in India and to make contacts with local healthcare providers in order to establish design goals for the assistive devices. The Michigan Tech Team visited the All India Institute of Medical Sciences (AIIMS), a comprehensive institute for teaching, research and patient care. Dr. Rajesh Malhotra, Professor of Orthopaedics and his team provided us with patient information and problems currently faced by children in India related to mobility/ambulation. Together, the need for a low-cost, low-energy consuming reciprocating gait orthosis (RGO) device that would suit the Indian culture was identified. Additionally the Michigan Tech Team visited Ms. Neena Macedo, President of the Delhi Council for Child Welfare (DCCW). Here more than 15 pediatric patients were identified and interviewed. The need for a low-cost caliper system to allow these children to better live in the Indian culture was identified. Several design criteria were dictated by patient health needs as well as societal and cultural aspects of living a handicapped lifestyle in India. This process of project identification will be executed in the future by the student team with guidance by the advisors during their delivery and project development visit.

**Figure 1.**A) traditional position for prayer for Indian culture. B) common position of squatting for Indian lifestyle.

The living conditions in India give rise to disabilities, including polio, that are either not seen or not prevalent in the US. Diseases such as club foot are treated very early if they occur in the US whereas in India the doctors often see patients very late and the diseases have progressed, presenting drastically different health challenges than seen in the US. With over 2/3rds of the India population living at or below poverty levels, the cost of health care and treatment options must be inexpensive. The Indian culture is one in which prayer is very important. Sitting cross-legged (Figure 1A) during prayer is something current gait assistive devices do not permit, yet traditional culture calls for. Additionally, Indian culture includes squatting for short and long periods of time (Figure 1B). When citizens are not lying down or walking, they sit cross-legged or squat for comfort. Most of the toilet facilities available in India are holes in the ground or fields in which squatting is essential to be able to go to the bathroom. Currently available assistive devices do not allow these positions to be attained. By producing a design that is user friendly, allowing the wearer to participate in the day-to-day cultural activities of his or her people, while maintaining low-cost affordability, this initiative aims to fill a niche of human need that has been ignored for decades.

## Projects

Two projects were identified for this first year of this initiative. The first team designed a knee-ankle-foot-orthosis (KAFO) (Figure 2A) device to meet the needs of local New Delhi children with gait affecting disorders such as polio and cerebral palsy. The team strove to create a KAFO that would not inhibit a child's daily activities with range of motion that allows the wearer to sit cross-legged and to squat down, while increasing comfort and decreasing cost. The team's design used a spring-action hinge to decrease the amount of effort needed to unlock the brace while still locking itself in place when the knee is straightened. By decreasing the weight and maximizing the durability of the product, the design was intended to give the children who use it an improved wearing experience for a longer duration. The second team designed a Reciprocating Gait Orthosis (RGO) (Figure 2B) device to aid in ambulation for children who suffer from cerebral palsy, polio, or spinal bifida. An RGO consists of braces for each of the legs that attach at the hip and incorporate some means for aided forward propulsion. The major goals of this project were to make an RGO that was significantly less expensive than products that are currently available and to enable users of the RGO to take part in normal daily activities such as squatting all while ensuring the device was low-energy consuming. Both teams were given design constraints/criteria that required their product to be innovative in order to significantly improve on what is currently available in India and the devices needed to be made from materials and tools available locally in New Delhi. While these products are available in both US and India, they currently do not have enough range of motion in the knee to allow sitting cross-legged and squatting and they are too expensive.

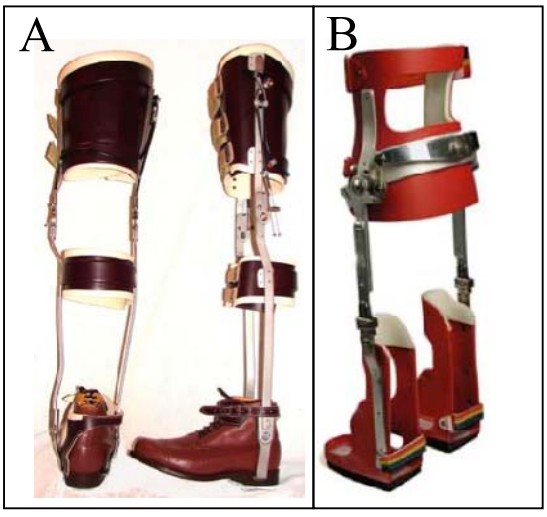


**Figure 2**. A) Standard caliper B) RGO http://www.centerfororthoticsdesign.com/isocentric_rgo/index

## Implementation

The international senior design option was implemented in the 2010-11 academic year. Students in MEEM 4901-Senior Capstone Design were given a list of 30 different projects, two of which were International Senior Design projects. Each student was asked to list their top 3 choices and to provide a resume. Eight (1 female and 7 males) students were selected to participate in the 2 international projects, with 4 students on each team. Each team was assigned a faculty advisor in the Mechanical Engineering Department. The students' first points of contact were Dr. Haut Donahue and Dr. Sorby who were sponsors of the projects. After initial meetings to define the design constraints, the students were encouraged to contact their respective sponsors in India.

Michigan Tech's Mechanical Engineering (ME) Senior Capstone Design (SCD) project is required for all students. The students in the International Design course followed the normal outline for the Senior Capstone Design course. Prior to enrolling in the year-long SCD course the students completed a 3-credit junior-level course that introduces the engineering design process; topics include thinking styles, teamwork, creative problem solving, brainstorming, Pugh method, technical report preparation, economic decision making, quality, analytical and experimental design optimization, DFA, DFM, GD&T, codes and fasteners, robust engineering, engineering ethics, patents and IP, and innovation in the workplace. Following this introduction to design, they enrol in the 2-semester SCD course sequence, where they work in teams on "open-ended" engineering design projects developing original and creative solutions to real engineering problems.

*Cultural and social barriers*. None of the Michigan Tech faculty or students currently involved speak Hindi. However, both Dr. Malhotra and Ms. Macedo, the two primary members of the India Team, speak fluent English. During our initial recruiting trip in April 2010 both Dr. Malhotra and Ms. Macedo translated for the Michigan Tech Team so we could talk to patients and employees at the facilities we visited. Part of the experience for the Michigan Tech students was to understand that the design challenges associated with this initiative would not exist if the children lived in the US. A specific example of a culturally derived technical constraints in these initial design projects is that the devices must provide a large range of motion (~120°) so that squatting and sitting cross-legged are possible; two positions critically important in Indian culture. This would be of minimal engineering importance under the US healthcare and health insurance system, but quite the opposite to achieve this functionality at the low-cost that is critical in the Indian market. These problems are unique to Indian culture; thus, properly defining the objectives and constraints (as done by a completing team during their concluding delivery and project development visit) relies upon truly understanding the culture. To facilitate this understanding, we planned activities for the Michigan Tech group throughout the year while they worked in the US. This included presentations by Michigan Tech Indian faculty and their spouses, regarding lifestyle, history, religion, and culture. We also had the students watch movies such as Namesake, and Slumdog Millionaire to gain an appreciation for Indian culture. Additionally, all senior design projects require regular group meeting with advisors and sponsors. Milestones were set throughout the 2 semester course so that there would be a working prototype at the end of the year.

The projects culminated in a faculty-led student trip to India to test the devices and to identify projects for the following year. The trip was set up to inlcude meetings and delivery to each location, identifying projects at current locations (NGO and AIIMS) and new locations (Jaipur), free "tourist" time, and follow-up visits were all part of the experience. The duration of the trip was eleven days, including two travel days at the beginning and one travel day at the end. We departed from the US on a Sunday (the day immediately after graduation) and arrived in Delhi on Monday night. Tuesday and Wednesday were spent at AIIMS and DCCW, respectively. Here the student teams met their Indian counterparts, whom they had been working and corresponding with over the previous academic year. The projects were delivered and arrangements were made to return the following week. On Thursday, the group travelled by bus and met with Dr. Anil Jain of Jaipur Foot. Jaipur Foot is a low-cost prosthetic (~$13) that is well-suited to the Indian lifestyle in that the person can go barefoot and walk on uneven terrain. Dr. Jain described his challenges in expanding the use of the Foot into other nations where a device such as this would fill a large need. Through these discussions we identified potential future research projects. On Friday, the group went back to Jaipur Foot for another presentation and to meet with current individuals who have been fitted with the device. Friday afternoon, Saturday and

Sunday were spent sightseeing in Jaipur and Agra. Monday and Tuesday were spent revisiting AIIMS and DCCW. The return visits to our partners enabled the students to see the RGO "in action" (the AIIMS team added padding and limb support for a specific patient) and to meet with craftsmen in the machine shop at DCCW to go over manufacturing details.

### Financial Plan

In these times of declining resources, implementing a program such as this needs to be accomplished with minimal financial input from the institution. Unfortunately, this means that the brunt of the cost of the program will necessarily be borne by the students. The Mechanical Engineering Department at Michigan Tech supported the cost of materials to build the design prototypes that were delivered to India. Each student who enrolled in International Senior Design was assessed a course fee that was significantly higher than students enrolled in the standard Capstone Design course. This course fee was then used to pay for ground transportation, lodging and food while in India. This fee also offset the travel costs of the two faculty who accompanied the students on the trip to deliver the projects.

### Challenges and Benefits

**Challenges:** The international component of these projects provided a unique set of challenges to the senior students beyond the expected traditional course-related design challenges. Practically there was a 9.5 hr time difference which needed to be overcome for meetings with the India contacts. Video conferencing, email and conference calls were the most heavily used means of communication. While the Indian contacts spoke English, there were still challenges for the students to convey their ideas and interact with a different culture. Additionally the students were required to ensure all parts used in the devices were readily available in India.

**Benefits:** During the delivery visit, the students were given the unique opportunity to identify design projects for the following year of students. This required the students to identify potential contacts, meet with them, understand the problems/challenges and identify design constraints. The only requirement was that the design projects (market opportunities) identified are for assistive devices aimed at helping those living in poverty. From an academic perspective, this final task brought the global experience full circle.

## Assessment

During the trip to India with the students, we posed 9 questions to the students to assess their overall experience and improve upon the process. The questions, a summary of their responses, and representative comments are included in Table 1.

| Question | Summary | Representative comments |
|---|---|---|
| Should we do this again? | All students said yes | 1) This was an incredibly worthwhile experience, both culturally and educationally. The chance to help others through engineering is the purpose for me choosing engineering. 2) This was far and away the most incredible and valuable experience of my undergraduate career. |
| Please provide comments regarding the timing of the trip | Mixed results. Most thought the end of the year was the right time to do this. | 1) Thanksgiving, the earlier the better to better understand the culture and project objectives and constraints. 2) The timing was great. Having it at the end of the year also gave us something to work and look forward to. |
| Please comment on the length of the trip | All students responded 8-10 days | |
| Please comment on the balance between work and tourist activities | All students thought the balance was excellent | |

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|---|---|---|
| What are some things we should have told you but we didn't? | How spicy the food was and about bargaining/hawkers | |
| What things should we change? | A variety of answers | 1) Set up the first teleconference or try and bring them to Michigan Tech. 2) Help students pay for trip. 3) Have a meeting close to departure 4) I'd like to see some ancient Indian sites as well as more recent Moghul ones. 5) More time to go off on our own. Time to relax. |
| What things should we keep the same? | The break in the middle for tourist activities. | |
| What would you tell other students thinking about this? | A variety of answers | 1)This presents a great opportunity to expand you culture diversity. Also, working on these projects will really open your eyes on how nice we have it; don't take things for granted. 2)This is a life-changing experience, something that has to be seen, touched, smelled to be understood. As far as projects go, tell students to get in direct contact with their collaborators from the start. |
| Why did you choose this project? | A variety of answers | 1) It was one of the few that didn't deal with engines. It also had a great impact on the people it was for. I couldn't pass up the opportunity to travel to India. 2) This project was my first pick because it had direct application of mechanical engineering concepts while benefitting humans in a visible way. 3) I really wanted to do a project that let me use my knowledge of engineering to make a meaningful contribution to people who don't have all the benefits of life I do. I have long been fascinated by India, and the opportunity to help Indian people with my education was entirely fulfilling. |

## Conclusions

The first International Senior Design offered through the Mechanical Engineering Department at Michigan Tech was a success by all measures. The sponsors in India were happy with the projects and the students felt they gained global experiences through choosing these projects and making the trip to India. As this project moves forward, the details of the trip need to be revised. The students felt that an early trip to better understand logistics would have been beneficial, but none wanted to give up the trip at the end of deliver the prototypes. Thus, a unique solution must be found to better equip the students with information at the beginning of the project. Overall the experience was found to be valuable to the students and will continue in the future.

**Figure 3: Students work with Delhi Council for Child Welfare staff to explain their leg brace design (left). Child at AIIMS trying on RGO with support of staff (right).**

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## Acknowledgements

The authors would like to acknowledge financial support from the Mechanical Engineering Department at Michigan Tech.