bridging

Students engineer innovative p

By Katie Neith

For most college students, the final weeks of summer are spent wringing out the last few drops of freedom and warm weather before the chill winds and tedious school days of autumn. But for a group of adventurous Caltech undergrads, those final days of break this year were spent touring smoke-filled factories, visiting dilapidated hospitals, and learning how to use every single part of a coconut. And all this in preparation for an engineering class that had yet to begin.

When one thinks of feats of engineering, modern and grand structures often come to mind: the Dubai Tower, the Large Hadron Collider, the International Space Station. But the primary objective of the field has more to do with utility than grandeur; it's about taking basic mechanical principles and drawing upon them to make tools and objects that will enhance people's lives.

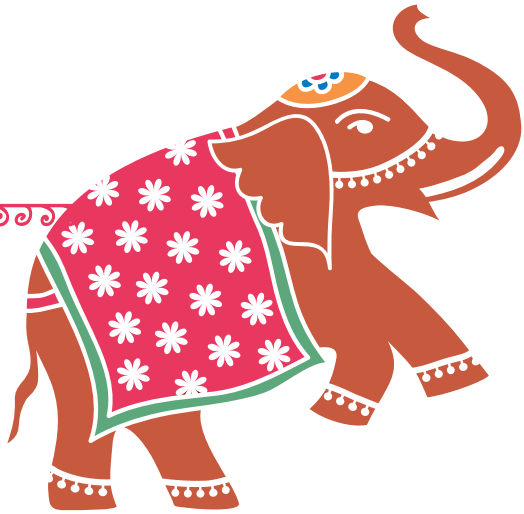
It was this concept that inspired nine of the students who were about to enter Caltech's E/ME 105 course to travel halfway around the world to India to learn firsthand about the needs of certain populations in rural areas of this vast and complicated country. They went knowing that their charge would be to return to Caltech and exploit the knowledge they'd gathered to develop useful and innovative products from scratch, with the help of the dedicated faculty and students who are part of a unique class that aims to tackle one of the greatest challenges of the developing world—lack of resources due to poverty.

"Product design has always been the most interesting part of engineering to me; the ability to create something that has never existed before is an exciting opportunity," says Blaine Matulevich, a senior with a double major in mechanical engineering and history. "The fact that this class allows me to do this while helping improve

A woman at the Akhil Rubber Mat Works cuts excess rubber from a mat. Each of the approximately 150 holes in the mat must be chiseled out by hand, causing pain and strain for the workers.

the gap

ducts for the developing world



the lives of less-fortunate individuals made enrolling in the course an obvious choice."

Aptly named "Product Design for the Developing World," this most practical of mechanical engineering courses—created and taught by Caltech visiting professor Ken Pickar—is part product design and development and part anthropological survey, giving students the opportunity to get up close and personal with the populations they seek to serve. The ultimate goal of the class is to teach the students how to take a product from the initial spark of an idea all the way to its implementation—and possibly even to gauge the success of the product once it's out in the market.

Through Pickar's collaboration with engineering faculty at the Saint Gregorios Institutes of Technology and Sciences (called Saintgits)—located in a rural area of the Kerala, a state at the southern tip of India—his Caltech students are not only assigned Indian student partners for the duration of the class, but a number of his students actually visit India just before the start of the school year, during which time they get a chance to meet and work with those partners.

"I think it's a great educational experience, allowing students to learn how the world works outside of their own neighborhoods and getting them to think about what people really need when they work on their designs, rather than designing what they *think* someone else might need," says Pickar. "I want students to develop a product that they feel strongly about."

Pickar—who worked at Bell Labs, GE Corporate R&D, and Honeywell before coming to Caltech in 1998—started his Developing World class in 2004. At the time, he says, his ideas for the curriculum were considered a bit "out there."

"Many of the classes at Caltech did not focus on teams or teamwork, and tended to use formal methods, like writing software codes to simulate what things should do," says Pickar. "That is all really cool stuff, but it also is removed from reality."

"This is possibly the most real hands-on class and one of the most unique classes we have here at Caltech," agrees Trisha Guchait, a Caltech junior in Pickar's class who started her studies as a chemical engineer but switched to mechanical engineering after a friend told her about the Developing World course.

During the first two years of the course's existence, students focused on an in-need population from anywhere in the world, and there were no trips or partner institutions. Then, in 2006, Pickar formed a partnership with a faculty member at Rafael Landivar University in Guatemala City, Guatemala: students from both institutions then worked together to find cheap, technological solutions for problems plaguing the rural populations in that Central American country.

The partnership—which also included students from the Art Center College of Design in Pasadena, in the hopes that the technologies developed would be aesthetically pleasing as well as useful—was a success, says Pickar. Such a success, in fact, that two of the members of the Caltech class, Rudy Roy (BS '07) and Ben Sexson (BS '07), went on to form a nonprofit called Intelligent Mobility International (IMI), which now provides to needy populations across Guatemala the safe, durable wheelchairs they first envisioned in Pickar's course. (See "Engineering for the Bottom of the Pyramid," in Random Walk, *E&S* 2007, No. 3.) The students exhibited their wheelchair at the Smithsonian Institute and won a Breakthrough Award from *Popular Mechanics*.

Three years ago, Pickar decided to shake things up, and he shifted the focus to India. The first Caltech trip to Kerala was in 2011. It was, says Pickar, "an inspirational and magical mystery tour."

STREET SMARTS

The nine Caltech undergrads who made the second trip to Kerala in September 2012 were welcomed to Saintgits by students and faculty

At Haven Homes for the Disabled—where resources are scarce—a table is strewn with rudimentary prostheses and the tools that will help build new prostheses out of existing parts.

members who had organized an expedition that would allow the students to get a firsthand look at the lives of local factory workers and hospital patients.

"The most rewarding experiences on the trip were the interactions we had with our fellow students, and with the many other Indian people who we got to know," says Matulevich. "I was really inspired by seeing how resourceful and innovative the Indian workers and entrepreneurs could be."

For nine days, Matulevich and his fellow students toured businesses in the area. They watched as women cracked cashews by hand using tools that could easily maim them with one false move; they looked on as other women working at construction sites used machinery clearly meant for much larger men. They toured factories filled with smoke and visited water sources choked with weeds. And they spent time at hospitals and homes for the disabled where resources like wheelchairs, prosthetic limbs, and rehabilitation equipment were severely lacking.

The group also met with the leaders of local nonprofit organizations that have unparalleled insight into the issues in the region. In fact, by the end of the trip, the students had visited or met with representatives from over 20 local companies and organizations. Only then, says Pickar, were they ready to even think about beginning the actual design process.

"We saw the problems, we framed them, but we did not try to come up with a solution on the trip," he said when he spoke with *E&S* in October of last year. "Now that the class has begun, we've begun going through a brainstorming process, coming up with possible solutions, and will soon build some prototypes."

"The trip is essential to make the eventual product development meaningful," adds Katja Luxem, a junior studying chemistry who took the class in 2011 and was so changed by the experience that she returned as a teaching assistant for the 2012 class, even traveling with the students and Pickar to Kerala. "It gives you a much better context for what the problem you're trying to solve actually is."

Guchait adds that she chose to go on the trip not only for the first-hand market research, but because she knew she would be able to see an India that most student-tourists never even glimpse.

"Knowing that I could go and see India with the students who live and study in Kerala really made me want to travel there," she says.

"I had the best time with the students from Saintgits, seeing how enthusiastic they were about all of the tours that we took to find issues to research for the class. Being with them and learning their culture was a lot of fun."

PRACTICAL PROJECTS

Once back in the States, the students who traveled to India recounted their experiences to the rest of the class; together, the entire class participated in brainstorming sessions, narrowing the list of possible projects down to eight. The students were then asked to list their top choices, after which Pickar assigned them to teams based on that ordered list. Each of the eight working groups includes at least one student who went on the Kerala trip, as well as two students from Saintgits, with whom the rest of the team often interacts during class lecture time via video-conferencing, Skype, and email.

Matulevich and his team are working to engineer a better wheelchair for the disabled people of Kerala, in much the same way that the Intelligent Mobility founders did for Guatemala. Wheelchairs are expensive and have a myriad of problems relating to comfort and reliability, he points out, so the team is strategizing to come up with economically and technically viable solutions to at least a couple of these problems.

"We are focusing on taking the wheelchair created by IMI and adapting it to fit the problems of rural India, as well as manufacturing it in India as cheaply as possible," says Matulevich. "To make the wheelchair affordable, being in India is actually a huge advantage due to their huge number of production facilities and a good infrastructure. At this stage, we believe that we will be able to reduce the cost of the wheelchair to less than a fifth of what it cost IMI to build it in Guatemala.

"My goals for this class," he adds, "are not only to solve the problem we've selected in a unique and successful way, but also to enjoy the process and learn new things about working with international teams and new approaches to design."

Guchait and her team are working on a problem she was made aware of during a visit to a rubber-mat factory where the employees—most of them women—manually punch holes in thick mats used in the shipping industry and as household products.

"Their company gets these mats from a larger rubber-mat factory that isn't set up to put in all the holes that are needed," explains Guchait. "So they ship them out to these women, who literally take a chisel and hammer and punch out each hole by hand, one after another."

Hammering and chiseling away at rubber all day is an ergonomic nightmare; that's why Guchait's team's goal is to create a hole-punching tool that will eliminate some of that strain on the women. They would also like to make the punching process faster so that the women can make more mats and, in turn, more money, she explains.

Students at Caltech hope new tools will make the job easier for rubber-mat workers like the woman above.

"I think our project is perfectly scaled so that we'll have a product by the end of the class that we can actually implement," she says. "That's my ideal goal—a finished tool that we can send to the women and that they will find useful."

Matulevich's search for a better wheelchair and Guchait's for a better hole puncher will be joined by similar efforts, including one aimed at devising a method to clear local lakes and ponds of a notorious weed that causes water loss, kills fish, and infests rice paddies. Another of the class's teams is working to design better face masks for employees who work in dust- or smoke-filled locations. And then there's the group that's working to convert organic

"We are focusing on taking the wheelchair created by IMI and adapting it to fit the problems of rural India."

A woman begins to weave a screw-pine mat. Handicrafts are the source of income for many rural women in India.

waste, such as kitchen scraps, into biogas as a low-cost alternative fuel source for homes and businesses.

To achieve its goal, each team will have to work within the very specific parameters Pickar has set. The students cannot use imported materials; everything they build with has to be found indigenously in India. Recycled or repurposed materials are even better. The product must also be strong; Pickar says he doesn't want anyone to compromise on quality. But most of all, it needs to be really, really cheap.

"If you were to design a product in the U.S., you would probably want the return on investment to be significant so that you get your initial investment back in a year or two," says Pickar. "With these products, we're talking about a month or two."

In other words, the product should be so useful and immediately productive that—even if you have to spend a little bit of money to make it—you would earn that money back quickly. For example, the biogas project team is looking at pricing its product to match the fuel costs for an Indian family over a month or two. Then, the team will drive the cost down even further by trying different, more affordable materials or recycled goods.

"Even though the technology in all of our projects is very simple, that doesn't mean they're not complex ideas," says Pickar. "The students need to really and truly understand the people who need their products, the human interactions involved, and the concept of building it at an insanely low cost. The challenges are very real and the designs reflect a lot of thought even though they may seem to be very simple."

Taking even a simple idea and bringing it to fruition, however, requires time. Which is why, this school year, Pickar's Developing World course was expanded to two quarters from just one. The idea, he says, is to allow students time to do a second iteration of their initial designs, as well as to focus on marketing—including hearing from guest lecturers who have seen success in commercial development.

"I am hopeful that we will have enough time to actually transfer some of our innovations to India," says Pickar. "I would be very disappointed if we didn't move some of these projects from idea to a usable product—maybe not all eight, but I'd like to see a couple go out into the world. The ones we've done in the past, we just didn't have enough time to do anything more than relatively crude prototypes. This is an engineering class, so we'd like to engineer something."

ENDURING IMPRESSIONS

Regardless of project success or final grades, Pickar and his students all agree that E/ME 105 is much more than a simple academic exercise.

"Most of the people who come to Caltech are not coming from poverty," says Luxem, the class TA. "For the most part, we are people who have been cushioned our entire lives, and it's important for us to realize that people who *haven't* been cushioned aren't any less smart, or any less talented. I recently heard a quote that said something like 'Talent is universal, but opportunity is not.' This class really puts that phrase into perspective. There are a lot of smart people out there living in poverty who just haven't been given the opportunity to get an education like we have, or to get the money they need to start a company."

For Guchait the core value of the class is the insight it's provided into how best to interact with people of a different culture.

"I really enjoy working with the students in India—they are so hardworking and possibly even more invested than we are since these products that we are making will affect them more directly," she explains. "They see the problems we are trying to address every day, so I think they really want solutions. And they know how and whether our products are likely to be accepted in India, from a cultural standpoint.

"The experience also made me realize that while other people may do things very differently, it's *their way* of doing it—that's what they are used to, so you can't just impose your ideas on them. Whenever you are making a product or trying to implement a solution, you have to make sure it will be acceptable to your target population."

Caltech students Katja Luxem (left) and Anish Agarwal (second from left), along with Abel Christina from Saintgits (second from right), inspect a waterway that has become clogged with weeds.

For Matulevich, the class is important because of how it encourages students like himself to approach engineering problems in new and interesting ways.

"Most classes at Caltech teach you math; this class teaches you to innovate. To me, that is one of the most useful skills anyone can develop," he says. "It also forces students to develop a global perspective, which is very important as technology and the increasingly global economy begin to blur the lines between different nations and cultures."

Even Pickar, a seasoned world traveler, finds that the trips continue to have an impact on him and play a role in the way his class has evolved. He spent some extra time in India this past year, walking the streets and speaking with people in some of the poorest neighborhoods in Ahmedabad—a city in northwest India—while visiting a school there.

"You take a superficial look and think, 'How can these people live under these conditions?'" he says. "But then you find that people who are very poor are not necessarily unhappy. You get the feeling, though, that if you could do things to make these people's lives better—

create products that they could use and enjoy—it would ease some of the pain they experience.

"But," he urges, "don't assume for a second that everyone is desperately waiting around for you to go do some cool thing to please yourself. You have to make sure what you do is really going to benefit other people."

And, in the end, that's what Product Design for the Developing World is all about: helping to bring others the tools they need to build a better world—a developing world—for themselves. E&S

Ken Pickar is a visiting professor of mechanical and civil engineering. His "Product Design for the Developing World" class was funded in 2012 by the George W. Housner Student Discovery Fund and by donors Rainer Schaaf, Paul Ouyang, and Rajiv Sahney (BS '85).