If an HIV-positive mother in the United States learned there was a 44 percent chance she could transmit the virus to her child through her breast milk, she would have a readily available solution to the problem: use formula.

In South Africa and other developing countries, however, the solution is not so simple. The World Health Organization recommends mothers breastfeed exclusively for six months not only because breast milk provides babies with essential nutrients and antibodies but also because formula is expensive in the developing world and could be mixed with unclean water. Yet more than 30 percent of pregnant women in South Africa are HIV positive, creating a dilemma for expectant mothers.

Enter students from the McCormick School of Engineering and Applied Science, who are eager to use their creativity to solve global problems like these. “The most pressing problems in the world, including global health, require both analysis and creativity,” says Julio M. Ottino, dean of McCormick. “Over the past several years our students have used these skills here and abroad with excellent results.”
Each year more than a dozen McCormick undergraduate and graduate students spend a quarter in Cape Town as part of the Global Healthcare Technologies study abroad program. They spend their days taking classes or observing doctors in hospitals, and their evenings working on design projects ranging from simple ways to kill HIV in breast milk to the construction of oxygen masks that don’t hurt the faces of premature babies.

“You hear about these problems, but seeing them up close is entirely different,” says Aneesha Suresh, a biomedical engineering graduate student. “Having the opportunity to design solutions has been really great. You’re given an opportunity and a responsibility.”

While working with doctors and patients in South Africa is a life-changing experience for these McCormick students, the school’s commitment to addressing the challenges of global health begins back on Northwestern’s Evanston campus. There students and faculty work year-round on projects that include creating anatomical models to better educate midwives and devising new diagnostic tests for use in rural areas.

Perhaps the most successful global health project to come out of McCormick is the p24 HIV test for infants. Developed in the lab of David Kelso, clinical professor of biomedical engineering, the test is quick and easy to use. A doctor or nurse can take a drop of an infant’s blood, place it on a plastic blood-separation membrane, insert it into a small processor about the size of an alarm clock, and get results within 30 minutes. The test is inexpensive—each will ultimately cost approximately $10—and will fill a niche.

Many HIV tests used in rural African clinics diagnose the virus by looking for HIV antibodies. Children of HIV-positive mothers are born with the virus antibodies even though they may not have the virus, so those antibody tests are useless in these critical cases. Other types of HIV tests can take weeks or months to produce results—too long for infants who need antiviral medications. Over the past six years Kelso and his lab, funded by the Bill and Melinda Gates Foundation, have developed a miniaturized, inexpensive version of the p24 test, which tests for antigens rather than antibodies.

“Sometimes mothers walk 18 miles to have their babies tested. Then they come back 30 days later and the test results aren’t ready,” says Kara Palamountain, executive director of the Global Health Initiative at the Kellogg School of Management and a collaborator of Kelso. “The new test translates into a lot of value for them.”

Now Kelso and his collaborators have created the Northwestern Global Health Foundation to manufacture and help distribute the test. It’s a new sort of business: a nonprofit biotech company that helps manufacture and deliver products that wouldn’t turn enough profit to make the cut at traditional companies. “The foundation is the bridge between research and the marketplace,” Kelso says.

“We’re trying to make sure the technology that comes out of the lab actually makes it to the market,” says Palamountain, who is also president of the foundation.

The Northwestern Global Health Foundation’s first client is the Clinton Health Access Initiative through UNITAID, which ordered 10,000 p24 HIV tests for field testing in several African countries. Clinics involved in the program measured Kelso’s portable test against their permanent testing equipment for accuracy. (Lab tests conducted before field testing began indicated the p24 HIV test was 96 percent accurate—much higher than required.) If successful, the test could be used in rural locations that don’t have the money or electricity for big, bulky permanent instruments.

The foundation has other tests on the way: Palamountain traveled to Uganda this year to research the market for low-cost HIV viral load tests, which tell HIV patients how well their medication is working. “The more virus you have in your body, the more likely you are to transmit it to others,” she says.

Kelso’s lab has also developed a tuberculosis test that uses the same technology as the p24 HIV test. Now it is conducting research to learn more about the clients it aims to serve. “We need to know who we are designing for,” Palamountain says. “We ask, Does the clinic have power? What is the temperature there? What is the skill set of the staff?”

The foundation’s earnings will be poured back into research and manufacturing—an exciting prospect for Kelso and Palamountain, whose goal is not to profit but to get life-saving tests to those who need them most. They hope the successful launch of the p24 test will give them credibility in the
African market and allow them to move forward with the viral load and tuberculosis tests. “If the foundation works, I think it’s an entirely new way to do business,” Kelso says. “It’s a new way to provide health care in an area that wouldn’t make profits.”

For Palamountain, visiting rural clinics where nurses see hundreds of patients a day for little money is motivation enough. “For me it’s a responsibility to make sure that others have access to health care,” Palamountain says. “The disparity between the haves and the have-nots really makes me want to do something about it.”

HEAT TREATMENT FOR BREAST MILK
Northwestern students in Cape Town are doing exactly that through the Global Healthcare Technologies program. They began working on the problem of HIV-infected breast milk two years ago. Student teams began by building on the practice in use at Mowbray Maternity Hospital in Cape Town: flash-heat pasteurization. Doctors heat breast milk before feeding it to infants, which inactivates the HIV but leaves antibodies and proteins unharmed.

The hospital had its own flash-heat pasteurization system but asked students to improve the system’s design so it could be used with greater ease at the hospital and in patients’ homes. A year ago a group of Northwestern undergraduates designed a system that employed the previously developed practice of putting milk in a peanut butter jar, then placing that jar in a water-filled pot heating on a stove. They created a special indicator to let mothers know when the milk was hot enough to kill the virus. It seemed simple. But when a new group of students arrived in South Africa this past spring, it became apparent that the system had problems. The shape of the peanut butter jar wasn’t optimal for heat transfer, most people in the Western Cape of South Africa used electric kettles instead of stoves, and people often heated the milk too long or too little. “If they heat it too little, they aren’t killing the virus, but if they overheat it, they compromise the proteins in the milk,” says Cassandra Harn, a biomedical engineering graduate student.

So the new group chose a smaller, more suitable jar—one from a widely available brand of jelly that costs the equivalent of a dollar—and rigged a frame using wires. They then hooked the wires onto the electric kettle and lowered the jar into the water. Then, when the electric kettle brought the water to a boil and clicked off automatically, the milk would be safe to consume. The system used resources that residents had ready access to and seemed easy to use.

The group’s initial tests, however, were anything but easy. “The milk was on the verge of dumping out every time,” Harn says. The team designed a new circuit to measure the milk’s temperature and tweaked its wire design so it was shaped like a spring coiled around the jar. The total price of each wire-and-jar system was only $2. Further tests are needed to verify that the virus will be killed through the heating, though initial results look promising. “The design isn’t glamorous, but it works for that locality,” says Matt Glucksberg, professor of biomedical engineering and an adviser in the program.

“This class took our skills from engineering, global health, communication, and business and combined them into one project.”

KEVIN LI

“As Americans, we want to use the most advanced technology in our designs,” says graduate student Aneesha Suresh. “But sometimes you just have to work on the most simple and cost-effective solution.”

Reaching that solution wouldn’t have happened if the team hadn’t traveled to South Africa, says Suresh. “It has been really beneficial to talk to the mothers and doctors here and assess the problem. Unless you’re here, you can’t understand what the problem is. We really wanted to be able to succeed and give back to the people we met.”

MAKING MASKS FOR BABIES
When babies are born prematurely in South Africa, mothers are encouraged to practice kangaroo mother care. In this method babies are kept in constant skin-to-skin contact with their mothers, allowing the mother’s natural body heat to regulate the baby’s temperature. Doctors find that premature babies often become healthy more quickly in kangaroo care than in incubators, but the method also makes it more difficult to monitor babies.

Several projects by Northwestern students in South Africa have focused on this issue. Some of these include mobile sleep apnea monitors and phototherapy devices for jaundiced babies in kangaroo care. This year a team of students designed a system that keeps premature babies breathing.

Many premature babies suffer from respiratory distress syndrome and require continuous positive airway pressure (CPAP) therapy to maintain the structure of their airways. The therapy is administered through the baby’s nose, either through a mask or prongs. However, the force applied by the mask or prongs (and the straps that hold them in place) can damage the baby’s nose and cause pressure sores that lead to infection and scarring.

“We focused on a new attachment method to minimize the forces on the baby’s face,” says Fei Yin Luk (biomedical engineering ’12). The team went to the newborn intensive care unit at the Mowbray Maternity Hospital and considered new solutions: perhaps a helmet or a face guard; perhaps something that attached to the bed frame and dropped over the baby’s head. Soon the students had a whole binder full of idea sketches. They eventually settled on a device that could be fitted to the caps that local women knit for babies in the hospital. It featured a noseguard fed by oxygen tubes and held away from the baby’s face by rigid aluminum straps. “It eliminated all that force on the babies’ cheeks,” Luk says.
Working in South Africa, the team found it difficult to create prototypes outside its usual shop in the Ford Motor Company Engineering Design Center at Northwestern. “It really opened my eyes and made me understand what engineering is like outside of the United States,” says Eric Liu (biomedical engineering ’12). “I have more of a global sense of engineering and see the benefits of collaborating overseas to get fresh ideas and to get feedback from people who have different needs.”

The team was satisfied with its prototype, but the project will likely be refined next year. Doctors and nurses at the hospital say they have trouble keeping the caps on the babies’ heads, and ideally the project would incorporate a design from another team: a visual force indicator that measures just how much force is being applied to a baby’s face.

“It’s difficult to do a study abroad experience in engineering,” Luk says. “The South Africa program is a great way to combine relevant education with an out-of-your-comfort-zone experience.”

EDUCATING MIDWIVES

Students back in Evanston are routinely challenged to move beyond their comfort zone as well. When a team of seniors in an undergraduate biomedical design course was assigned the task of creating a model placenta to help educate midwives in developing countries, the students had a few questions: What does a placenta look like? What does it feel like? Why is it important?

“I never even knew the placenta came out after the baby,” says Kevin Li (biomedical engineering ’11).

The students soon learned that the developing world has high rates of postpartum hemorrhaging, often because midwives—who usually assist at births—don’t understand techniques for effectively birthing the placenta. If they pull too hard on the umbilical cord or fail to notice abnormalities, the consequences could be fatal.

The team set out to create a low-cost model that could help midwives learn how to handle the placenta. Students headed down to Northwestern Memorial Hospital and surveyed OB-GYNs. They had doctors use a force gauge to show how much force was needed to birth a placenta. They witnessed a birth and afterbirth, and they observed and felt a real placenta. They then headed to the lab of John Vozenilek, associate professor of emergency medicine and director of the Center for Simulation Technology and Immersive Learning. There Vozenilek uses realistic materials and sensors to create teaching models for medical students and doctors (see related story on page 14).

Under Vozenilek’s supervision the students ordered several current placenta models. How heavy were they? What did they feel like? How was the umbilical cord attached? They decided their model placenta had to be more realistic and cheaper than those currently available. It had to include abnormalities such as blood clots or missing pieces so midwives would be prepared for any eventuality. And because it would be used in developing countries, the model couldn’t rely on a power source. Then the students experimented with EcoFlex, a silicone-based rubber, and created several less-than-realistic models—some were too red, too brown, or too stiff—before finally getting the details just right.

Next the team set about creating a feedback mechanism that would tell midwives when they were pulling too hard. After designing and building one complicated device, the team hit on a much simpler solution: using magnets to attach the cord to the model placenta. That way, a midwife could practice pulling the cord, and if the magnets separated, she would know she pulled too hard. The team bought magnets from a local hardware store and, seeing that they worked perfectly, ordered specified-force magnets. The students brought their model back to the hospital for doctor testing, and then a group of Kellogg students took the model to Africa to get feedback there. “Everybody liked our model,” says Tina Chaudhry (biomedical engineering ’11).

“It is brilliant in its simplicity,” Vozenilek says. “The students needed to design a model that was durable and inexpensive, and they were able to create a device that’s highly useful for that environment.”

The team entered its design in the Rice Global Health Technologies National Design Competition and won third place. That success led the students to take an independent study during spring quarter to write a scientific paper about the model and develop a business plan to market it. “We want to see where it can go,” Chaudhry says. “We want to see it succeed. This project has the possibility to make a real difference.”

Though they have all now graduated, the students agree that the project has helped prepare them for the workplace. “This course took our skills from engineering, global health, communication, and business and combined them into one project,” Li says. “It was the first time I saw how all those elements came together to create a piece of work. What we accomplished still surprises me. It shows that students can definitely create devices with high impact.”

Opposite: Mitzi Franken, a nurse, and Lucy Linley, neonatologist-in-charge at the School of Child and Adolescent Health at the University of Cape Town, with McCormick students Graham Marcy, Eric Liu, and Fei Yin Luk.

Above left: David Kelso with the p24 HIV test processor.

Left: Graduate student Cassandra Harn (right) in Cape Town.