A classroom project to design a machine to process baobab fruit became an engineering leadership effort unlike any other.

Photos by: Curtis Chan

BY CURTIS CHAN

AN UNEXPECTED journey

A RANDOM EMAIL AND AN UNUSUAL FRUIT SEND PENN STATE ENGINEERS ON AN AFRICAN QUEST

For a team of Penn State engineering students, what started as an ordinary class project became an extraordinary, life-altering expedition, taking them to and from Africa three times in a single year.

"It was an engineering practicum class to apply leadership principles," recalls mechanical engineer **Matt Zellers**. "It was 'pick a project,' so another student and I picked baobab. It sounded cool."

Not native to North America, the baobab fruit looks like a cross between a coconut and a potato. For Africans, it serves as a source of food and income.

Faced with either writing a report about the baobab's uses and business models for selling the fruit or designing a machine to process it, the students decided to go the engineering route.

Turning the baobab's raw insides into something edible takes some effort—the seeds and fiber must be sifted out before the remaining chalky pulp can be ground into a powder.

Though a bit tart to the taste, the baobab's highly nutritious content makes it a popular choice by natives for meals and drinks.

A crude tumbler machine was developed to crush the pulp and filter the baobab's innards, but Zellers admits it didn't work as planned. "It was a generation-zero machine. But it was a start."

With the project and semester over, Zellers uploaded the machine's accompanying PDF report onto his website's e-portfolio, expecting never to revisit it.

Or so he thought.

Nearly 5,200 miles away in a tiny Internet café in Africa, a simple Google search for "baobab extraction" was keyed into a computer.

The first hit was for a site selling machines to press baobab seeds into oil. The second was for the Penn State paper.

Zellers picks up the story: "On Oct. 27, 2010—I looked up the date—I got an email from this girl named Ashley. She wrote: 'Hello, sir, my name is Ashley and I live in a village called Pingou in the Republic of Benin. I'm in a women's cooperative that processes baobab fruit manually using mortars and pestles efficient ways to do this. We saw your report. Would you be interested in helping us with this project?'"

Not quite sure what to do, Zellers approached one of his teachers, **Richard Schuhmann**, the former Walter L. Robb Director of the Engineering Leadership Program.

Since much of the leadership program centers on collaborating with other cultures, the email inquiry presented a perfect opportunity for some of Schuhmann's students to put theory into practice.

"It was a request for a piece of technology to help the members of the cooperative have greater food security, improve their standard of living, increase the quality of product that they're producing, and perhaps even become participants in the global economy," Schuhmann says.

The effort became a capstone design project for the spring, and the two recruited a student team of designers and fabricators, including mechanical engineers **Steve DeSandis** and **Leigh Lesnick** and industrial engineer **Alyssa Joslin**.

"We started from ground zero. I wanted everyone to give a fresh take on things. I didn't even show them the old prototypes," Zellers says.

With a goal of delivering a machine to the cooperative by the end of spring semester, the team's work began in earnest.

"It's a tough fruit to deal with," DeSandis states. "It's tough to get the pulp out of. The workers crack it open, essentially smacking it against concrete. Once it's open, they scoop out the insides with their hands. It has veiny-like fibers with pulp and seeds."

They researched similar devices, such as coal crushers, peanut de-shellers, and salt and pepper grinders, to get inspiration.

Zellers recalls the heated debates on how to proceed. With eight weeks left before their self-imposed deadline,

During some down time, the Penn State engineers went on safari in Pendjari National Park in northwestern Benin, sighting elephants, hippos, antelope, and numerous birds.

the engineers went through a number of prototypes, but none functioned properly.

"Steve texted me the Sunday after spring break and said, 'I got a prototype that works.' He said it worked like a dream," the Pittsburgh-area native says.

The machine wasn't much to look at. "It was made from chicken wire, attached to a drill, held together with duct tape and balsa wood. It was terribly inefficient, but it functioned really well."

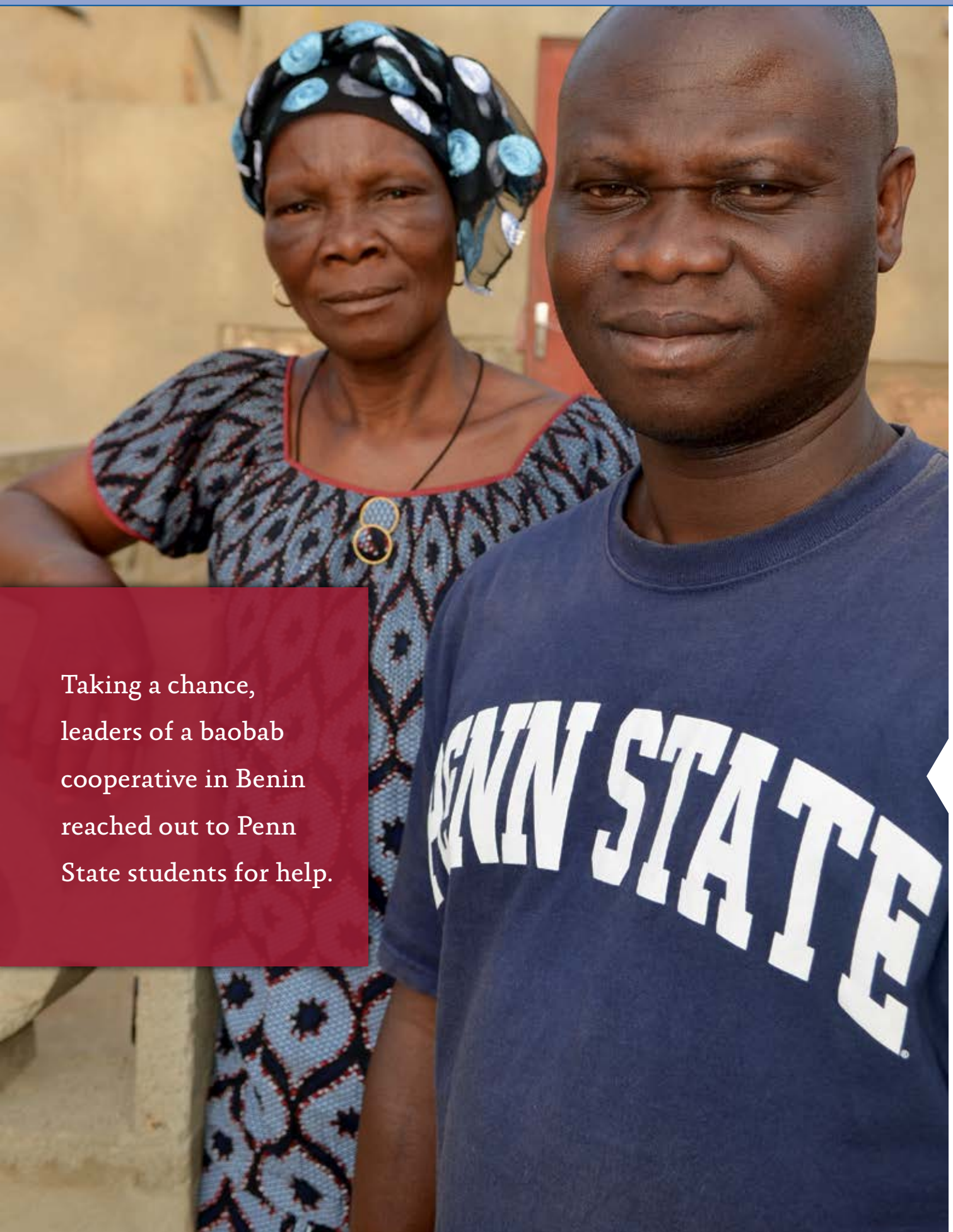
For the team, it was the 25th prototype. "You could see bits and parts from all of the other prototypes. We had learned a lot from the entire process," Zellers states.

A final prototype, which resembled an arcade pinball machine made of stainless steel, was built to take to Benin.

Raw pulp is dumped into a hopper at the top of the machine. A series of rollers crushes the pulp while a metallic mesh separates the baobab powder from the seeds and fiber.

Joslin, explains, "The machine tries to take away the really strenuous parts of processing baobab. The women in the cooperative have to pound it using a giant mortar and pestles for a good 20 minutes. It really takes a toll on their hands, necks, backs, and arms."

DeSandis says, "Once that's done, they take it to a sieve where it's refined and then packaged to sell."



Taking a chance, leaders of a baobab cooperative in Benin reached out to Penn State students for help.

Cooperative manager Brice Gbaguidi discusses the finer points of baobab processing with students Matt Zellers and Leigh Lesnick.

DeSandis says inefficiencies in the procedure leads to valuable baobab powder being lost. The students designed the machine to be more efficient, capturing powder that would otherwise have been wasted.

"In the traditional process, we lose a lot of product," states Brice Gbaguidi, the cooperative's production manager. "We want the percent we lose to be very little."

Lesnick says, "My hope is that this machine makes their lives just a little bit easier and fits in with their culture. We want to make something useful for them that they will accept."

Gbaguidi adds that a working baobab machine would allow the cooperative's women to work on a project to expand their output. "They would have more time to plant baobab."

With support from Penn State's Office of Global Programs, four students—DeSandis, Joslin, Lesnick, and Zellers—along with Schuhmann and research associate **Audrey Karim**, set off to Benin in May 2011.

The idea was for Schuhmann, Joslin, Lesnick, and Zellers to head to Benin right after concluding a week-long leadership project* with Hungarian business students at Corvinus University in Budapest. DeSandis was to fly from Philadelphia with the machine—now disassembled into five large, cooler-style bins—and meet the rest of the team during their overnight layover in Paris before heading on to Africa.

** A story on the trip by engineering leadership development students to Hungary was featured in the previous issue of Engineering Penn State.*

An extremely labor-intensive effort is required to process raw baobab fruit into a consumable product.

In addition to food and drink, baobab is used for makeup, candy, and other products sold in Africa and Europe.

FIFTH-BOX FIASCO

It was the wall of humidity slamming into the Penn Staters as they deplaned in the port city of Cotonou that Zellers remembers the most.

"It was hot, humid at 10 o'clock at night. It was like 85 degrees with 100 percent humidity," the mechanical engineer recalls.

The plan for the engineers was to spend Monday meeting with the Université d'Abomey-Calavi's faculty, then drive north on Tuesday to the villages of Pingou and Natitingou.

But a problem all too common to air travel emerged: one of the boxes was missing.

Assured by local airport officials that the errant trunk was on the next daily flight from Paris, the Penn Staters continued with their itinerary.

Unable to demonstrate a fully assembled, working machine, the team quickly improvised. As luck had it, all of the parts necessary to display the machine's basic functions were present—only the bolts, fasteners, bearings, sprockets, gears, and chains needed to link together and drive all of the components simultaneously were missing.

They demoed its different features—how it crushed raw baobab and sifted the powder from the seeds—to the Abomey-Calavi deans and faculty.

"The professors at the university characterized the machine as 'remarkable,'" Schuhmann recalls.

Despite the success, the Americans still had a problem: Monday's flight from Paris did not produce the missing box.

Cotonou's airport officials reassured them the fifth box would arrive on Tuesday's flight from Paris.

Waiting another day for the chest was not an option—the team's itinerary scheduled four full days in Pingou and Natitingou to work with the cooperatives, and the drive to reach the country's north takes a full day.

With a timetable to keep, two drivers from Abomey-Calavi ferried the Penn State contingent to the villages with the understanding that another driver would bring the lost box immediately on arrival.

DEALING WITH ADVERSITY

Benin is a sliver of a country on the continent's southern coast. It's not very wide—from east to west along the Gulf of Guinea, it's approximately 50 miles. But the trip from Cotonou to the northernmost part of the country is nearly 300 miles.

On an American highway, such a trip takes just a few hours. Benin's roads, however, are anything but modern.

Outside of the city limits, the relatively smooth asphalt is replaced by a moonscape of potholes, forcing the drivers to slow down and swerve constantly.

All manner of vehicles ply the two-lane stretch, and "share the road" is the rule of the day. With oncoming traffic also swerving to avoid potholes, driving includes playing lots of chicken.

The Beninois demonstrate a special talent for piling people and materials into—and onto—their transportation. The dilapidated vehicles are crammed with passengers and saddled with sacks filled with charcoal or freshly picked pineapples, papayas, and mangoes in a mind-boggling display worthy of any game of Jenga. Motorcycles—by far the country's most popular mode of transport—carry everything from multiple travelers to long steel rebar to—no lie—refrigerators.

Well, *small* refrigerators.

The result is a ten-hour trek filled with fits and starts. Though it was still hot when the team reached Natitingou at sundown, the humidity wasn't as relentless in the country's interior.

Meanwhile, a cell phone call from Cotonou bore no good news—Tuesday's flight from Paris included no box.

Repeated calls to the airline were an exercise in frustration for Schuhmann. No one was sure whether the missing case left Philadelphia, was stuck in Paris, or wound up somewhere else on the planet.

"I just felt numb. I felt so hopeless," Zellers recalls. "I couldn't do anything. I couldn't call anyone. It was a terrible feeling. It was something I wasn't used to."

Thoroughly frustrated at having traveled so far and not being able to assemble the baobab machine, the team didn't submit to panic.

As the students continued to cling to the hope that the box will somehow turn up, the engineers made the most of their visit. Again,

On the team's first trip to Benin, left, they could only give the cooperative a glimpse at the fruit processing machine. Zellers returned at the end of the year with a smaller—and functional—machine.

Zellers states, “That was the biggest lesson from the trip: use local parts, labor, and materials.”

they demonstrated the machine’s different aspects for the cooperative.

“The students did exactly what we wanted,” Gbaguidi says.

For the four students, the trip gave them valuable, first-hand experience on how the cooperative gathers, processes, and packages baobab fruit by hand.

“We asked the women of the cooperative if we were to make the machine manual, would they prefer something that was hand-cranked, or maybe something with pedal power? We asked them if they prefer to work in groups, or not in groups—just a bunch of questions so we can make an ever better machine next year,” Lesnick says.

The cooperative’s women, including its president, Véronique Sétondji, gave the team very clear directions on what they wanted.

And because the lost parts—easily replaceable in the United States at any hardware store—aren’t common to Africa, the team made multiple expeditions into town to research what parts are readily available.

Ideas for a second baobab prototype were sketched out. Perhaps it can use bicycle-style pedals and gears? The ubiquity of Chinese-made motorcycles throughout the country, along with repairmen and spare parts, made the team consider building the next device using compatible motorcycle components.

Zellers states, “That was the biggest lesson from the trip: use local parts, labor, and materials.”

As if the lost box wasn’t disheartening enough, heavy storms during the Benin’s rainy season washed out some roads in the region, aborting the planned trip to Pingou.

Despite the disappointments, the trip proved to be fruitful for the engineers. They gathered valuable, on-site information from the intended users of a Penn State baobab machine, and they cemented a relationship started by a single, random email.

“From a short-term perspective, it may have been a failure because of the missing box,” Schuhmann says. “However, from a long-term perspective, the absence of that one container forced us to look away from the current design and begin looking into the future and thinking about the next version of the device.”

At the end of the week, the team left Benin—with a promise to the cooperative to bring a working machine.

A SECOND CHANCE

Although the team's return to the United States marked the end of spring semester, that didn't stop them from planning the next machine. Throughout the summer of 2011, the students discussed improvements and changes that could be made, based on their experience in Africa.

Like the first machine, this second iteration became a senior capstone design project for the fall semester. More students were brought on board to help the effort.

"They took our design and made a generation two," Zellers explains. "They had specific goals: reduce the weight by 50 percent, reduce the size by 50 percent, and increase the durability."

The team also didn't want to repeat the lost luggage incident. "We pushed them so we could make it carry-on size. The final machine was 26-inches long and fit in duffel bags," Zellers says. "They worked their tails off—they did a great job."

New machine in hand, Zellers and Schuhmann flew back to Benin in December.

But problems arose as the two attempted to demonstrate the fully assembled machine.

"The new design did not use the proper motor. We use 120-volt sockets. In Africa, they use 220-volt sockets," Zellers states.

He continues, "Because we didn't know much about electricity, we thought we could just get one of those converters you buy when you go overseas."

It worked, but the machine's motor ran much faster and the unit's casing was very hot to the touch.

Thinking that a transformer should solve the problem, they purchased one in Natitingou.

"We plugged it in and it started smoking, so we quickly unplugged it." Believing it to be a bad transformer, Zellers and Schuhmann purchased a second transformer—this one equipped with fuses.

But each time a fuse was popped into the transformer and flipped on, it would blow.

"We thought, 'Why wasn't it working?'" Zellers says. "It was because the power wasn't high enough to handle to load from the motor."

A local motor repairman told the two that the second transformer wasn't up to the task and lent the engineers a much larger, more powerful transformer.

The new transformer did the trick, and the cooperative had a working baobab processing machine.

But because the transformer was borrowed and the engineers feared that the motor might be burned out, they decided something had to be done.

"We didn't want to leave these people with something that didn't work."

Where would they find a replacement motor?

The Penn Staters didn't have to look far—they still had the original four boxes left from the earlier trip, which included a perfectly working motor.

But an obstacle presented itself—the new machine was designed to only work with the smaller motor. The old motor had to be adapted to fit the new chassis.

"It had different feet, it had a different key shaft size, and it had a different base height to it," Zellers explains. "How could we put this motor on our machine? That, in retrospect, was the lesson from trip number two—how to design a transmission system with a power source to the process that could be fixed or changed with parts in Africa."

So they took the motor to an auto lathe shop in the village and had the unit's shaft shaved down, the motor's bottom cut off, and a new base welded on.

With the sun setting on the team's final day in Natitingou, the motor was installed and successful—the machine was processing baobab.

"I was relieved. We finally came through," Zellers says. "We fulfilled our promise."

The cooperative's workers allowed the students to experience firsthand the rigors of processing baobab.

A MACHINE FOR AFRICANS BY AFRICANS

Throughout the spring of 2012, the baobab team, which now included civil engineering senior **Tyler Pritz** and mechanical engineering graduate student **Erick Froede**, along with Joslin and Lesnick, continued to iterate the machine.

Though plans fell through to work with a British company dedicated to selling baobab, a grant Schuhmann received from Proctor & Gamble geared toward African development gave the team the idea to transfer the baobab processing technology.

Each spring break, Schuhmann travels with a contingent of Penn State engineering leadership students to Morocco. The thought was to use the Proctor & Gamble funds to bring the baobab group to Morocco, team with engineering students at the Ecole Mohammadia d'Ingénieurs (EMI) in Rabat, and build a duplicate baobab machine using African parts and equipment, thereby transferring the technology.

The aim, says Froede, "was to 'Africanize' it and empower those who can implement and most directly benefit from the technology."

So four students—Froede, Joslin, Pritz, and Zellers—began working with their Moroccan counterparts to build a duplicate machine in three days.

"It was nice that our team got to Skype with them beforehand, but there is nothing equivalent to meeting in person," Pritz says. "We hit it off with our teammates immediately and formed strong bonds quickly."

Pritz says the Americans had to adapt to the Moroccans' procedures at EMI. "[We] had grown accustomed to the relative freedom we had when producing our machine at Penn State. There, the professors and shop instructors wanted to be included in every step of the process and do a majority of the actual machining themselves."

Froede adds that EMI's machine shop is different from Penn State's Learning Factory and doesn't use computer-aided technology. "Everything had to be done by hand, so even creating a simple circle within a piece of sheet metal became an arduous task."

With some very long hours, the team met its goal of building an African version of the Penn State baobab machine.

"It took 37 hours to redesign in metric and fabricate," Zellers states. "We proved that it could be done there."

Civil engineering student Tyler Pritz, right, works with a Moroccan student to fabricate a crucial part for an African version of the baobab machine.

Mechanical engineering graduate student Erick Froede, right, said producing an African version of the baobab machine required building many parts by hand.

ENDS AND BEGINNINGS

Looking back two years later on his involvement in the leadership development program and his three trips to Africa, Zellers says, "Hands down, that defined my college career. At all my job interviews, that's all I talked about—my experience with baobab and the Engineering Leadership Development Minor."

After graduating in May, Zellers accepted a job as an associate sales engineer with the Timken Co., a bearings and power transmission manufacturer in Canton, OH.

DeSandis graduated in May 2011 and now serves as a technical support engineer with Siemens Industry. After receiving their degrees this past May, Lesnick works as a secondary mathematics teacher with Teach for America and Pritz is a marine engineer with the firm AECOM.

Froede is completing his graduate degree at the University, while Joslin is finishing her senior year.

But the baobab effort continues with another group of students and another new machine.

Joslin is leading the student effort to develop a fifth version of the machine.

Although Schuhmann left Penn State in August to pursue a teaching opportunity at the Massachusetts Institute of Technology, his successor, **Mike Erdman**, plans to return with students to deliver another machine to Natitingou's village cooperative this December.

And the fifth box remains missing. ■