IBI* SERIES WINNER

Engaging Undergraduates in Global Health Technology Innovation

"Appropriate Design for Global Health," the IBI Prize–winning module, primes students to respond to global health challenges with novel technological solutions.

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It takes only 90 minutes to fly from Miami to Port-au-Prince, Haiti, but the cities are a world apart. A baby born in Port-au-Prince is nearly 10 times as likely to die before age 1 as an infant born in Miami. Life expectancy on the island is almost 20 years shorter than in the United States. That such disparities persist despite renewed public and private commitments to improve global health illustrates the need for a new generation of innovators who recognize the challenges and can design and deploy new health-care technologies that are both highly effective and affordable (*1*). In response, we and others have developed educational programs to engage globally minded health-care innovators (*2*). Our approach is inspired by a Haitian saying that captures the essence of inquiry-based education: "You don't learn to swim in the library; you learn to swim in the river."

We created Beyond Traditional Borders (BTB), a program to train undergraduates from all majors to work across disciplinary and geographic borders to design novel technology solutions to real-world global health challenges (*3*). This curriculum has been institutionalized as a minor in global health technologies at Rice University and has engaged more than 10% of the university's undergraduates in its classes. It has also been adapted for high school students (*4*).

The introductory inquiry-based module is "Appropriate Design for Global Health." Students learn to use the engineering design process to develop innovative technologies addressing global health challenges. To inform their designs, students learn about important global health issues, the framework to understand factors that limit and facilitate access to health technologies, and the role that new technologies can play in solving global health problems. Students also examine case studies of successful global health interventions (*5*).

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*IBI, Science Prize for Inquiry-Based Instruction; www.sciencemag.org/site/feature/data/prizes/inquiry/.

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Hit the road. Throughout the design process, students are mentored by health-care providers in the developing world. Exceptional students travel to the developing world to implement their designs in partnership with health-care professionals.

Design challenges are identified by partners who provide health care in low-resource settings. For example, one challenge was, "Develop an accurate method to determine hematocrit that does not require electrical power." Additional challenges can be found in the supplementary materials.

As teams design their solutions, they work to (i) define the problem, (ii) develop a solution, (iii) create and test a working prototype, and (iv) refine and present the solution. Health-care providers and engineers in the developing world and the United States mentor students, and they can revise their work appropriately. Through literature reviews and communication with mentors, students identify constraints that their solutions must satisfy. Guided by their own problem statements, teams design technologies that can be taken into the field and demon-

Get real. Students design technologies to solve real global health challenges. The efficacy of the student-designed bubble CPAP technology is now being evaluated in clinical trials in Malawi.

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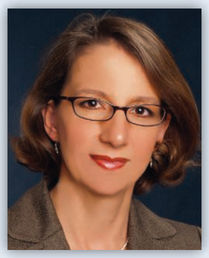
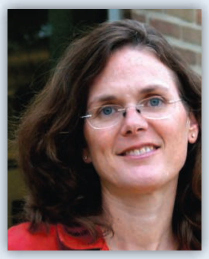
About the Authors



Rebecca Richards-Kortum is the Stanley C. Moore Professor of Bioengineering at Rice University. Her research integrates advances in nanotechnology, imaging, and microfabrication to develop point-of-care diagnostics for low-resource settings. Richards-Kortum established Beyond Traditional Borders in 2006. She is a member of the National Academy of Engineering and served on the National Academies Committee on Conceptual Framework for New Science Education Standards.



Maria Oden is a professor in the Practice of Engineering Education and directs the Oshman Engineering Design Kitchen at Rice University. Oden has developed engineering design courses that emphasize open-ended problem solving of real-world design challenges.

Lauren Vestewig Gray is Executive Director of Rice 360°: Institute for Global Health Technologies at Rice University. She helps build international collaborations that have led to internships for more than 60 students and partnerships with high schools around the "Bioengineering and World Health" curriculum, which has been taught to more than 2000 high school students.

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strated to health-care providers for feedback during extended summer internships. Technologies are expected to meet all appropriate safety and regulatory standards.

Exceptional students who are selected for internships in the developing world demonstrate and, in some cases, implement the technologies under the guidance of trained health-care providers (see the first photo). Interns are assigned three tasks: demonstrate technologies and gather feedback, develop and implement a solution to another challenge identified by the host site, and pinpoint new design challenges.

Since 2006, BTB students have developed 58 technologies. Many students continue to improve their technologies through independent study. For example, a team designed a hand-powered centrifuge that can be constructed for $35 using a salad spinner. Laboratory testing showed that the centrifuge is as accurate as a commercially available centrifuge costing 10 times as much (*6*). Students designed light-emitting diode–based phototherapy lights to treat neonatal jaundice. The lights can be made for less than $100, whereas the cost of commercially available phototherapy lights can exceed $6000. An institutional review board (IRB)–approved clinical study in Guatemala found that the low-cost lights are as effective as conventional phototherapy in treating neonatal hyperbilirubinemia (*7*). Another student designed a portable, battery-operated fluorescence microscope that can be made for $240. Results of the low-cost microscope for detecting *Mycobacterium tuberculosis* in sputum smears were concordant with those from a laboratory-grade fluorescence microscope in 98.4% of cases (*8*).

Two student-designed technologies have been distributed broadly in the developing world. The Ministry of Health in Ecuador is using 25 diagnostic labs-in-a-backpack countrywide. About 214,000 "DoseRight" syringe clips, which fit into the barrel of an oral syringe to ensure accurate dosing of medication, were recently delivered to Swaziland. The clips are being used by 12,000 participants in the country's national Prevention of Mother-to-Child Transmission of HIV/AIDS program to ensure that infants receive the proper dosage of liquid antiretroviral medication. The technology has been licensed and is now available commercially, with preferred pricing for GAVI Alliance countries (*9*).

We are preparing a third technology for countrywide dissemination. Two years ago, a team developed a robust, low-cost bubble CPAP (continuous positive airway pressure) system to assist babies in respiratory distress in the developing world. With support from the National Collegiate Inventors and Innovators Alliance and the U.S. Agency for International Development, the system has been refined and is now undergoing an IRB-approved clinical trial in Malawi (see the second photo). One of the students on the design team is working with physicians in Malawi to implement the trial.

Students participating in the design courses were surveyed to assess whether the course project enhanced their skills. Compared with other civic research or design courses at Rice, a greater fraction of global health technology students reported enhanced skills in creativity, leadership, ability to effect social change, and ability to solve real-world problems. International student interns report that the internship had a strong impact on their career intentions; 95% of interns indicated that they intend to include global health as an important part of their careers.

We have discovered that giving students the opportunity to solve real global health problems not only creates leaders for tomorrow's global health technology workforce but also produces technologies with the potential to revolutionize health-care delivery in poor settings. The shared challenge now for universities and organizations that train students to develop global health technologies is to create a strong pipeline that bridges the divide between student-designed prototype and commercialized product. Only when the path to commercialization is well marked will the tremendous promise of these technologies be realized.

References and Notes

1. S. R. Sinha, M. Barry, *N. Engl. J. Med.* **365**, 779 (2011).
2. Similar programs that focus on global health technology innovation exist at Northwestern University, Duke University, Johns Hopkins University, Columbia University, Stanford University, Massachusetts Institute of Technology, and a growing number of other universities.
3. M. Oden, Y. Mirabal, M. Epstein, R. Richards-Kortum, *Ann. Biomed. Eng.* **38**, 3031 (2010).
4. "Appropriate Design for Global Health" and a companion class, "Bioengineering and World Health," have been adapted for high school students. The Texas Education Agency approved the curriculum to count toward the state's graduation requirement in science. Since 2007, more than 2000 Houston-area high school students have participated; 77% are underrepresented minorities. Course materials are freely available online at www.owlnet.rice.edu/~bioe301/kortum/index.html.
5. R. Richards-Kortum, *Biomedical Engineering for Global Health, Cambridge Texts of Biomedical Engineering* (Cambridge Univ. Press, Cambridge, 2010).
6. A. R. Miller *et al.*, *PLoS ONE* **5**, e11890 (2010).
7. J. Brown *et al.*, *Am. J. Trop. Med. Hyg.* **85**, 327 (2011).
8. J. V. Colindres *et al.*, *J. Trop. Pediatr.* (2011). 10.1093/tropej/fmr063
9. DoseRight, www.doseright.com.

10. Beyond Traditional Borders is made possible by a grant to Rice from the Howard Hughes Medical Institute through the Undergraduate Science Education Program. The authors gratefully acknowledge contributions from the many domestic and international partner organizations listed in the supplementary materials.

Supplementary Materials

www.sciencemag.org/cgi/content/full/336/6080/430/DC1

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