THE WATER AND HEALTH IN LIMPOPO INNOVATIONS FELLOWSHIP PROGRAM

An NIH funded post-doctoral training grant

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Project Summary / Abstract

The Water and Health in Limpopo (WHIL) Innovations fellowship program will provide cross-disciplinary training in global health innovation to twelve post-doctoral fellows, six from the United States and six from rural Southern Africa, over the next five years. The program will focus on the closely related issues of poor access to water and sanitation in rural areas of Southern Africa and unacceptably high rates of morbidity and mortality associated with early childhood diarrhea. The nearly decade old collaboration between the University of Virginia (UVa) and the University of Venda, South Africa that will host this program is led by the internationally-recognized global health leader and early childhood diarrhea (ECD) specialist, Dr. Richard Guerrant, at UVa, and by Dr. Pascal Bessong, UNIVEN Professor and Chair of Microbiology. The collaboration is supported by a multi-disciplinary group of faculty from both institutions with particular expertise in enteric disease, rural water purification strategies, rural nursing, community planning, agent-based modeling, child development, cross-cultural ethnography, and South African law related to water and human rights. This group has formed over the past four years and has developed protocols and strategies for trans-disciplinary and trans-oceanic coordination, scholarship, and training. The WHIL Innovations fellowship will provide promising doctorally-prepared potential global health leaders from the US and Southern Africa with the opportunity to participate in mentored global health research and education training with a particular focus on access to and quality of water and ECD. Major objectives of the training program are: (1) To build skills necessary to engage in innovative global health research collaborations including specific tailored training in community engagement, rural water management, measurement of impacts of ECD, simulation modeling in global health, trans-disciplinary collaboration, global health research ethics, project management, and laboratory management; (2) To conduct an innovative, mentored global health research project in the context of the multi-disciplinary WHIL program; and (3) To develop a portfolio of research and training outputs that will serve as a framework from which to develop individual efforts and as a resource for future fellows and other trainees. We plan to recruit fellows from many disciplines and expect to attract outstanding candidates thanks to our well-established and diverse faculty training group. We expect that our trainees will contribute meaningful new research relating to rural water and sanitation provision and ECD in the context of the WHIL program. More importantly, we will ensure that they are prepared to think with innovative pragmatism about these issues meaning that, as they develop exciting new interventions, processes and policies, they will anticipate and incorporate questions of community acceptability, efficacy, affordability, accessibility, and scalability.
Limpopo Province, South Africa: Burdens of Disease and Poverty

Limpopo Province, like much of rural South Africa, faces “quadruple” health challenges related to the crippling burden of HIV/AIDS; other infectious and nutritional diseases; non-communicable diseases; and injury-related conditions. (Bradshaw, et al., 2006)

Located in the northeastern corner of the country, it is a predominantly agricultural province, which suffers from the highest rates of poverty (34%) in the Republic of South Africa and reports the lowest rates of accessible drinking water (44%) (see Figure 1). (Coovadia H, 2009)

This confluence of low income and inability to access clean water contribute to unacceptably high rates of diarrheal disease and associated mortality. The age-standardized death rates from diarrhea are 1.5 times higher than the national average and 3 times higher than the neighboring Gauteng Province, where Johannesburg and Pretoria are located. Diarrheal disease is second only to HIV disease in terms of life years lost in Limpopo Province. (Bradshaw, et al., 2006) (See Figure 2) While the death rates from diarrheal disease are appalling, they fail to measure another important effect of diarrheal disease, the tragic loss of human potential due to the negative impacts of repeated bouts of diarrhea on children’s physical and cognitive development. (Dillingham R, 2004) (Checkley W, 2008)

Since the mid-nineteenth century, we have known that improved access to clean water and sanitation reduces diarrhea rates. (Guerrant RL, 2003) (Esrey SA, 1985) However, billions of people in resource-limited settings, like Limpopo, still lack water and sanitation. (Dillingham R, 2004) Reviews evaluating the effects of water supply and sanitation interventions in resource-limited settings note that while improving water quality and/or quantity reduces diarrhea rates, the effects are not as large as predicted. The authors attribute this lack of effect in part to lack of community engagement and identify the need for more comprehensive studies that include: longer follow-up; better outcome measures; attention to socio-behavioral aspects such as affordability and acceptability; programmatic issues of sustainability and scalability; and cost-effectiveness analyses. (Clasen T, 2007) (Arnold BF, 2007) (Fewtrell L, 2005) An instructive example is the story of the Playpump, a child-powered merry-go-round that was to provide water in rural areas of southern Africa. Despite celebrity endorsement and policy-makers’ approval, the appealing idea foundered.
due to poor site selection, inadequate maintenance, and low community acceptability. (Costello, 2010) Therefore, the promise of better child health was not kept, and, in some communities, water actually became less available, as the old systems had been dismantled.

Clearly, excellent global health researchers have struggled for decades to develop and document strategies to decrease childhood diarrhea through the improvement of water and sanitation. Untold millions of dollars have been expended in these important efforts, but they are not enough. We must train a new cadre of global health researchers who are prepared to imagine new solutions and, perhaps more importantly, to “tweak” the knowledge that we have about water and sanitation interventions. In a recent article, Malcolm Gladwell argues that the “tweakers,” like the late Steve Jobs and many 19th century British engineers, have made the most meaningful contributions to society because they “tweaked” (the signature interventions of the industrial age) — refined and perfected them, and made them work.” (Gladwell, 2011) Indeed, we need new, diverse, interdisciplinary, and pragmatic global health researchers who can assess the state of the field of diarrhea prevention and identify the opportunities for innovation — taking what we know and making it “work.” In the context of this proposal the definition of innovation will be: “a new implementation of a product, process, policy, or paradigm (that) creates an outcome that is more effective, affordable, accessible, easier to use or deliver, and/or provides superior scalability.” (PAR-12-003: Limited Competition: Framework Programs for Global Health Innovation (D43), 2011)

The Water and Health in Limpopo Collaboration: A Platform for Innovation

The University of Virginia’s (UVa’s) Center for Global Health and the University of Venda (UNIVEN), located in Thohoyandou, Limpopo Province, began collaborating in 2002 when Dr. Guerrant was first invited to go to UNIVEN by an UVa colleague in environmental sciences. The environmental science departments at the two universities had been collaborating on climate change, and the leadership at UNIVEN requested that an emphasis on health be included in the program. Dr. Guerrant traveled to UNIVEN where he met Dr. Pascal Bessong, then an instructor in microbiology and now the South African Principal Investigator on this grant. Dr. Guerrant invited Dr. Bessong to apply for a post-doctoral fellowship at UVa in virology. Dr. Bessong successfully competed for that fellowship, spent two years at UVa, and has returned to UNIVEN where he was named head of Microbiology and is now a full professor. From this relationship between mentor and mentee, a large and productive collaboration has emerged and provides a firm foundation for the development of a post-doctoral training program focusing on innovative, trans-disciplinary solutions to the socio-behavioral, engineering, environmental, and policy challenges that impede increased access to water and sanitation and thus prevent meaningful reductions in childhood diarrhea in Limpopo Province and throughout rural sub-Saharan Africa.

The closeness and importance of this collaboration to both institutions was formally recognized with a tele-conferenced Memorandum of Understanding signing between the Provost at the University of Virginia, Professor John Simon, and the Vice Chancellor of the University of Venda, Professor Peter Mbati, in December 2011. (Please see letters of support from both leaders.)

UVa’s Center for Global Health: Training the Global Health Leaders of the Future

Dr. Guerrant created UVa’s Center for Global Health (CGH) in 2001 as one of the first pan-university Centers for Global Health. CGH was built on a 33-year program in Geographic Medicine and our sustained collaboration with the Federal University of Ceará (UFC), in Northeast Brazil, one of the longest collaborations in the United States. In partnership with the Division of Infectious Diseases and International Health, CGH has collaborations with institutions in several countries including Brazil, Haiti, Bangladesh, China, the Philippines, Ghana, Uganda, Tanzania, and South Africa. Dr. Guerrant and the other faculty and staff associated with CGH bring their collective wealth of knowledge and experience in international research and training collaborations to the proposed project.
UVa’s CGH seeks to advance global health both through direct research and through building the capacity of institutions and the next generation of international researchers. This human capacity is built through the academic and grant support of scholars and fellows as well as the development of curriculum. This three-pronged approach has particular relevance to the proposed project. (Lorntz B, 2008)

- **Student Scholars**: UVa student scholars develop intensive faculty-mentored 6-8 week projects in underserved countries, working to improve the health of those in greatest need. Students from all disciplines apply for support to conduct service-learning and community-defined research projects in collaboration with faculty and professionals at UVa and in the host country, promoting collaborative learning, service, and research. Since 2001, CGH has sponsored 89 UVa students to travel to UNIVEN to work with our partners. These students have supported existing projects, sparked new ones, and developed a lasting interest in global health.

One student from the College of Arts and Sciences at UVa articulated her experience this way:

"Conducting research as a Center for Global Health Scholar has been one of the greatest experiences of my career at UVa…. I was a part of a research team that conducted research on ceramic water filters and the potential health benefits to rural villages without consistent access to clean water. During the academic year, I got to work closely with a team comprised of undergraduates, graduate students and faculty mentors. … I got to work in an interdisciplinary team of engineers, doctors, nurses and foreign affairs students as an economics major. This experience has made me want to continue work with an international or non-profit component long beyond college."

- **Research Fellows**: International research fellows, who are typically junior faculty at their home institutions, travel to UVa from collaborating sites abroad for training and research relevant to their own research priorities. Through exchange with these international collaborative partners, CGH fosters research and service programs in underserved settings, to strengthen capacity and competence in science. Of over 80 fellows trained through this program, four have come from UNIVEN, staying at least two years and then returning to UNIVEN. Our international fellows’ continued research alliances with UVa faculty result in shared discoveries, patents, grants, and publications (over 200 to date). All too often international training results in opportunities for overseas physicians and scientists to move permanently to the US (the “brain drain”). Our strongly articulated philosophy and documented track record is precisely the opposite: to attract the brightest and most innovative researchers who are strongly committed to returning home after their training because they recognize that the opportunities for further progress on their research priorities are greatest in their home countries. Our fellows’ program and UNIVEN’s participation in it provides an important model for the proposed training program.

- **Multidisciplinary Curricula**: CGH works closely with the Department of Public Health Sciences and the new program in Global Development Studies to develop interdisciplinary global health curricula. (Please see letter of support from Professor Richard Handler.) We have supported the development of individual courses which incorporate global health in 6 different schools at UVa. In addition, the Center helped to create a Global Public Health minor in 2006 which has now become a track in the Global Development Studies (GDS) major. In its second year, the GDS Global Health track receives two times as many applications as it is able to accommodate. Through the development of these courses and pathways, we have become familiar with the depth and breadth of faculty interest in global health teaching and mentoring. We also have developed substantial teaching resources to introduce students at all levels and from diverse backgrounds to critical issues in global health policy and research. This curricula will provide important foundations for the proposed training program, allowing, respectively, for the identification of mentors from diverse fields and for efficient orientation to critical issues in global health for those fellows who may come from other fields.
The University of Venda (UNIVEN): Building the Future of rural Southern Africa

Founded in 1982, UNIVEN is a rural-based comprehensive University located in Thohoyandou in the Vhembe district of Limpopo Province. UNIVEN is a Historically Disadvantaged University in a former South African Homeland during the colonial and apartheid eras. UNIVEN serves a population of students who are usually the first members of their families to attend college. The students have special connections and commitment to the communities around their university. These connections are reflected in UNIVEN's commitment to rural development.

UNIVEN's vision is to be at the center of tertiary education for rural and regional development in Southern Africa. The University has established itself as an engine that drives economic growth and development in the Limpopo Province and the Southern African Region. It offers degrees and diplomas in Agriculture, Education, Environmental Sciences, Health Sciences, Human and Social Sciences, Law, Management Sciences and Mathematical and Natural Sciences. Committed to quality and excellence, its academic offerings concentrate on professional and career-focused programs both at the undergraduate and postgraduate levels.

Presently UNIVEN is home to approximately 10,500 students and more than 300 academic staff members. Its institutional culture is based on the core values of quality and excellence, accountability, transparency, integrity, respect, diversity and social responsibility.

UNIVEN is geographically well situated to conduct research in the fields of rural development, indigenous knowledge systems and indigenous law. It is located in an area where traditional governance structures continue to be vibrant in people’s daily lives. Simultaneously, it is the closest institution of higher learning to three of the most significant archeological and historical sites of pre-colonial southern Africa: Mapungubwe, Thulamela and Great Zimbabwe.

UNIVEN’s research output is increasing significantly. In 2009, publications increased by 71%. In addition, in the past two years, significant new resources have been allocated that are critical for further increases in research output. A state-of-the-art Chemistry and Life Science research building has been erected, and new faster internet connections have arrived. In tandem with new facilities, UNIVEN has enacted new policies to promote research, such as reducing teaching loads for researchers, and has also created new positions to support proposal writing and research publication. The University maintains research ties and conducts collaborative research with universities and research institutions nationally and internationally and is receiving increased recognition from these research collaborations. For example, researchers from UNIVEN are part of the 'International Network for the Study of Malnutrition and Enteric Diseases' (MALED) which is led by Drs. Guerrant and Bessong and is described in more detail below. Of note, “water research for improved quality of life” is one of UNIVEN's eight niche areas of research and is clearly related to the goals of this proposal.

UNIVEN provides particular academic leadership in fields such as Indigenous Knowledge Systems and African Linguistics. Researchers from UNIVEN have made substantial and positive contributions in the fields of rural development and poverty alleviation through the multi-disciplinary Center for Rural Development and Poverty Alleviation (CRDPA). The Center's mission is to strive to provide effective leadership in people-centered action research, and teaching and learning in response to the multiple and complex poverty-related challenges of rural communities in Southern Africa. This Center has won international recognition and hosts post-doctoral fellows from South Africa and the Southern African Development Community (SADC – an alliance of 15 sub-Saharan African countries committed to improving the well-being and quality of life in the region). The Director of the CRDPA has visited UVa several times and frequently mentors UVa students. UNIVEN is also a leader in the field of Community Engagement. The Directorate of Community Engagement supervises all students visiting from UVa who are involved in community-based projects. The Director, Professor Netshandama, spent a post-doctoral year at the School of Nursing at UVa and has worked closely with the Institutional Review Board at UVa to harmonize ethical review practices at the two universities and with the communities who participate in our research. Finally, the UNIVEN law clinic provides access to legal services to people living in the communities surrounding UNIVEN and advises UNIVEN/UVa collaborations
when community members need legal advice. These unique areas of expertise will enhance the proposed training program.

The collaboration with UVa fits into UNIVEN's mandate to internationalize. UNIVEN promotes internationalization in all aspects of its core business of teaching and learning, research and community engagement. UNIVEN attracts students, staff members and researchers from the entire African region as well as from other continents. It presently has 87 international staff members and 581 international students, 74 of whom are postgraduates, providing an important pool for recruitment for the proposed program. The majority of international students hail from the Southern African region (e.g. Zimbabwe, Botswana and Lesotho) allowing UNIVEN to make a significant contribution to regional development through offering them quality higher education. UNIVEN has a dedicated International Relations Office (IRO) which coordinates international activities and serves as a resource for international partners, students and visitors. Mr. Cornelius Hagenmeier directs this office, has visited UVa to develop the UNIVEN/UVa collaboration's strategy, and is committed to providing the administrative support requisite for the success of the proposed training program.

As noted in the support letter from Vice-Chancellor Mbati, UNIVEN looks forward to the opportunity to support collaborative post-doctoral training of its own students and to attract other well-qualified students from around Southern Africa. The proposed program provides a unique offering that should enhance recruitment and retention of junior research-oriented faculty members to this leading institution in rural and regional development.

**The Framework Program in Global Health: Building Water and Health in Limpopo (WHIL)**

In 2006, UVa competed successfully for one of the first Framework Program in Global Health awards. The Fogarty International Center offered these awards to promote the development of global health education across US campuses. Since that time, UVa’s Framework Program has built infrastructure at both universities to foster and support student interest in global health educational and research opportunities primarily for undergraduate and pre-doctoral students.

In Charlottesville, we first used the Framework funds to promote and sustain the development of twelve new courses in six schools at UVa through a course development grant competition. Course topics range from a history course examining tuberculosis in Native Americans to a chemistry course exploring the role of metals in global health to an urban planning seminar to design sustainable food systems. These courses provided global health electives necessary for the development of a global public health minor at UVa, which was sponsored by the Framework program and which has now transformed into a Global Development Studies major.

The support for developing course proposals as well as the meetings and seminars to bring faculty members interested in global health education together allowed us to identify a key group of UVa faculty interested in pursuing collaborative teaching and research in global health. The group includes the Framework’s PI and the PI of the proposed training program, Richard Guerrant, and the Framework program’s director, Rebecca Dillingham. Both are members of UVa’s Division of Infectious Disease and International Health and have ongoing research programs in enteric disease and HIV in resource-limited settings respectively. In addition, three faculty from the School of Engineering and Applied Sciences are involved. James Smith, a civil engineer, specializes in point-of-use water treatment in resource-limited settings. Garrick Louis, a systems and civil engineer, focuses on a systems approach to developing sustainable water and sanitation systems in resource-limited settings. Gerard Learmonth, also in systems engineering, brings expertise in the use of information technology to organize and manage complex data sets as well as substantial experience with agent-based modeling. Karen Firehock, a faculty member from UVa’s Urban Planning department in the School of Architecture, brings extensive experience in community mediation of environmental issues, particularly water supply issues. Marianne Baernholdt from the School of Nursing contributes to a systems approach to improving quality of care in rural areas, especially in resource-limited settings.
Representatives of this core faculty group traveled to UNIVEN in both May and December 2008, with partial support from the Framework grant, to plan a collaborative research and education program. At UNIVEN, we held joint faculty workshops to explore the possibility of expanding our collaboration around shared research and educational goals. Based on the group’s expertise as well as the needs articulated by communities near UNIVEN, we focused our collaborative work on developing sustainable strategies to improve access to water and sanitation while monitoring health outcomes in real time. This program was named, Water and Health in Limpopo (WHIL), and, with support from a supplement to our original Framework grant, we launched the program in 2009, as described in the next section.

Of note, in the context of developing WHIL, we created protocols for interacting within and between universities as well as with our community partners. These protocols have now been tested and refined and provide important structure for the collaboration which will benefit the proposed program. At UNIVEN, the partnership is coordinated through the office of Vhonani Netshandama, Director of Community Engagement and Professor of Nursing. At UVa, the Center for Global Health coordinates the project from fiscal and administrative standpoints. With funds from our Provost’s office, we currently support a half-time field site coordinator, Ms. April Ballard, to help manage this growing project. She has nine years of experience working with international fellows and faculty and has been particularly helpful with maintaining adequate faculty communication, coordinating student engagement, monitoring institutional review board submissions, and documenting project progress. We hope to make her position full time in the context of this proposal to reflect the additional coordination required for integrating faculty involvement in the post-doctoral training program.

At the faculty level, steering committees made up of three team members from each university direct the overall management and budget of this project. Steering committee members from both sides participate in conference calls on a quarterly basis. Standing faculty meetings occur every other month during the academic year for UVa faculty members to discuss research question development, data collection and analysis, student selection, publication planning, and fund-raising. We have piloted video-conferencing with UNIVEN for these faculty meetings which is felt by faculty at both universities to enhance the meetings. Professor Jeanita Richardson from Public Health Sciences at UVa led the process of formalizing protocols to facilitate interactions between UVa and Univen faculty and students.

At the student level, we have also reflected on how to create equitable partnerships between learners from different institutions and cultures. While issues of academic credit and authorship immediately come to mind, we have found that issues of socio-economic and cultural differences also require attention. For example, we have iteratively addressed how students eat together in the field. Although we have learned how socioeconomic and educational disparities between our partners take sustained, persistent effort to change, we have found that change can occur. (Krizancic C, 2011) Simple transactions, like sharing food (or not sharing it), may substantively impact cross-cultural collaborations, and we have learned to prepare our students for these issues and to mitigate negative interactions.

In addition to developing the WHIL project, we used our supplemental Framework funds to support the development of a course called, Global Health Research Methodologies (Public Health Sciences 5185/7185), in Spring 2009. Collaboratively taught by Dr. Dillingham and Professor Learmonth, this course introduced students from engineering, medicine, nursing, arts and sciences, and commerce to global health research, using case studies from the WHIL project. The class was offered for the third time in the fall of 2011 and has been incorporated into the regular offerings of the Public Health Sciences department, thanks to student demand. This course provides an important opportunity to recruit undergraduate and graduate students to the project and as a platform for teaching experiences for potential post-doctoral candidates recruited into the proposed program.
As mentioned above, we have had the opportunity to receive a supplement to our original Framework grant and to apply for and receive some private foundation grants to support WHIL’s activities. Since its launch, a diverse group of nine UVa Faculty members from five schools (Engineering, Medicine, Architecture, Nursing, and Arts & Sciences) have constituted the sustained core of the WHIL project team at UVa. UNIVEN faculty members from five of the University’s eight schools partner with us. (Law, Environmental Sciences, Health Sciences, Management Sciences, and Maths & Natural Sciences.) Fifty-nine students from seven schools at UVa and from UVa’s own rural-based campus at UVa-Wise in southwest Virginia have participated in our field research activities from 2008-2011. (see figure 3) Dozens of UNIVEN students have participated in field and academic work on UVa/UNIVEN teams.

In 2009, WHIL launched in two communities near UNIVEN with a small trans-disciplinary team of UVa and UNIVEN students and faculty who conducted baseline community assessments including a complete census, water quality testing, and GIS mapping of water sources, sanitation facilities, and households. Univen faculty members from nursing, public health, microbiology, hydrology, GIS, and planning have been and remain engaged in these efforts. In fact, two UNIVEN team members traveled to UVa thanks to Framework supplement funds in January 2010 to collaborate with UVa faculty on data analysis from summer 2009 and to plan the summer 2010 research season.

In addition to the quantitative data collection, three qualitative projects using Photovoice, a research methodology that promotes community engagement, (Wang C, 1997) have been completed. These projects recruited community participants of diverse ages to work with student researchers from both universities. The participants took photos and gave semi-structured interviews to share their perspectives on issues surrounding water and health in their communities. The information gathered from the Photovoice projects has guided our prioritization of projects. Specifically, the research signaled to our group that the community’s priority was access to a greater supply of water not to water of better quality. Therefore, we focused our work on the development of an improved water supply system by our engineering teams. (Cunningham, 2009) In addition to the information gathered and published from the Photovoice project, it also established significant community trust. The photos taken by the participants were exhibited, with their permission, at the UNIVEN campus and have now become a permanent exhibit. They were also displayed at UVa. This opportunity to have words and images transferred from the community to the university transcended boundaries that had not been previously
This spirit of meaningful community collaboration is also exemplified by the collaboratively designed logo representing the WHIL project’s linkages between the two universities and the communities. (See Figure 4)

In response to the Photovoice findings, we first focused on water supply. Led by Professor Garrick Louis, the Water Supply and Sanitation (WASAN) team evaluated options for increasing water supply to our partner communities. In conjunction with community volunteers, a slow sand filter design was selected. This structure was planned, erected and refined in the summers of 2010 and 2011. To reach its objectives of a sustainable water supply, the WASAN group is training village volunteers and working with the village water committee to build, operate, and maintain the system. The opportunity to develop new community-led strategies for development and implementation is an important opportunity emerging from this part of the project. A systems engineering graduate student reflected on what participation in the WHIL project meant for his education.

"Thanks to the project, I have had the privilege to work with doctors, nurses, educators, businessmen, undergraduates, graduates, regional leaders, national suppliers, and of course, the actual stakeholders of the projects' local community. Such exposure to ... a varied set of disciplines, expertise, or prominence cannot be easily found at this or other educational institutions. ... the WHIL project gives participating students the opportunity for experiential learning. Moreover, this chance is not just extended to UVA students, but also the other stakeholders – UNIVEN, community members, suppliers, etc. – that gain just as much from the experience. Last, but not least, the WHIL project provides a very important service that is necessary in modern times... global perspective."

While working on the water supply was a first priority, our initial investigations had also established that available drinking water in the communities rarely met World Health Organization (WHO) standards. Therefore, Professor Jim Smith and Dr. Dillingham worked with graduate students in public health and engineering to pilot a point-of-use ceramic water filter intervention in the region. Professor Smith had previously tested these filters in a community-based study in rural Guatemala. (Oyanedel-Craver, 2008)

In Limpopo, we recruited HIV+ individuals from a clinic that provided antiretroviral therapy (ART). In our population, over 48 weeks of follow-up, the individuals who received the filters (intervention) experienced a significantly lower number of days of diarrhea compared to those who did received water use education but no filters. (0.3 days/week compared to 0.06 days/week (p< 0.001)) (See figure 6) (Abebe L, 2010) In addition, the filters were considered acceptable and desirable by the participants in the study as well as in a community-based survey conducted by WHIL students in our partner communities. A willingness-to-pay study was included in the survey which allowed the team to establish a price point for the filters, in the event that they would be commercialized. (Tyeryar M, 2011) The information gathered about the use and acceptability of these specific ceramic water...
filters provides an important opportunity for future research, described further below. In addition, proposals for training programs for undergraduates and for graduate students which center on the optimization and life cycle analysis of these filters have been submitted to the National Science Foundation with Professor Smith as Principal Investigator and other WHIL faculty as co-investigators.

Another aspect of the WHIL project is a school-based health and hygiene education program for children. Requested by the community, this part of the project has highlighted the need for creative strategies to transmit messages about health and hygiene behaviors and to promote behavior change. We look forward to developing a partnership with the Vuwani Science Center, affiliated with UNIVEN, and led by Professor Vaith Sankaran, a co-investigator on this proposal. The Science Center has learning laboratories at their main campus as well as mobile classrooms which are designed for primary and secondary school students in the region. It also has expertise in indigenous knowledge systems. The combination of these areas of expertise will provide another opportunity for innovation.

As evidenced by our descriptions above, our original Framework grant allowed us develop a global health curriculum, interdisciplinary educational and research collaborations, and to build trans-national partnership. Our supplemental funds permitted us to create a new model of engaged scholarship where faculty and students from many disciplines worked together to gain skills, create knowledge, and to report and implement findings relevant to a specific community’s self-identified greatest health challenge. The opportunity to work across disciplines, cultural, linguistic, and socio-economic divides in the context of a strong research partnership has allowed students and faculty to cultivate a diverse skill set ranging from technical expertise to logistical savvy to cultural humility. We believe that our model of a sustainable, collaborative, organized, and integrative approach to student and faculty engagement in global health research will support a robust post-doctoral training program.

The WHIL-Agent-Based Model (WHIL-ABM): A Pilot Innovation

In 2010, an opportunity to propose a pilot project in Global Health Innovations emerged from the Framework program. Our group successfully competed for this one year pilot program by proposing to develop an agent-based model of early childhood diarrhea (ECD) in our partner communities, the WHIL-ABM. Agent-Based modeling and simulation provides a framework in which the structure and behavior of a complex system, such as that surrounding the prevention of ECD in resource-limited settings, can be better understood and even fosters the generation of new knowledge. In addition, the WHIL-ABM allowed us to create an effective matrix for trans-disciplinary collaboration. In 1992, Rosenfield described the trans-disciplinary approach as one in which "researchers work jointly using a shared conceptual framework drawing together disciplinary-specific theories, concepts, and approaches to address a common problem." (Rosenfield, PL, 1992) Kessel and Rosenfield more recently provided a review of the trans-disciplinary approach and identified factors associated with its success. The WHIL-ABM structure includes all of them: a compelling unifying question; a supportive, trusting team; and opportunities for co-mentoring of students. (Kessel F, 2008)

Agent-based modeling and simulation is a widely used methodology for analyzing complex systems. It is a computer simulation tool that allows the representation of the decision-making elements of a complex system, termed agents, to be represented in software and equipped with simple decision rules that capture, at a sufficient level of detail, the actions that agents might take in the modeled environment. For instance, an agent-based model of birds might use a few simple rules to characterize their flight—don’t fly too close to another bird (separation), fly in the average heading of neighboring birds (alignment), and steer to move toward the average position of neighboring birds (cohesion). An agent-based model of bird flight with a collection of simulated birds following only these three simple rules quickly gives rise to discernible system-level flocking behavior that cannot be predicted on the basis of individual bird behavior. Likewise, in a public health model, persons (“agents”) following simple rules may lead to quite unexpected community (system) level outcomes.

Recent publications have demonstrated the potential of ABMs to assist global public health practitioners, as they face challenges ranging from appropriate implementation of insecticide-treated bednets (ITNs) for malaria control with respect to different vectors (Gu W, 2009) to development of recommendations about vitamin D supplementation, (Diffey, 2010) to predicting the course and preventing transmission of pandemic
influenza. (Shi & Keskinocak P, 2010) (Perloroth DJ, 2010) These in silico experiments were accomplished more rapidly than observational or interventional trials and at less cost. They also revealed unexpected findings such as the need to assess individual vector susceptibility to ITNs and the differential efficacy of school closure in mitigating influenza spread.

With the support for our pilot grant, we developed the WHIL-ABM in an effort to capture the complexity of ECD and to define strategies or sets of strategies to diminish rates of ECD through identification of emergent system behaviors. Key participants in the effort included: Dr. Sheree Pagsuyoin, a post-doctoral fellow in civil engineering, Mr. Jeff Demarest, a masters’ student in Systems Engineering, and Mr. Jonathan Mellor, a PhD candidate in civil engineering. Professor Learmonth, Dr. Dillingham, and Dr. Guerrant coordinated the development of the model with regular input from other faculty members and review by an external advisory committee.

An on-going collaborative research project at Univen provided a unique asset to the development of the WHIL-ABM. In 2009, through its partnership with UVa, Univen became one of eight international sites in the Malnutrition and Enteric Disease (Mal-ED) Network, which is conducting a 5-year prospective study of childhood diarrhea and malnutrition. The Mal-ED Network is funded by a $30 million grant from the Bill and Melinda Gates Foundation to the Foundation for the National Institutes of Health, and the University of Virginia plays a coordinating role for four of the eight sites, including Univen. Dr. Bessong is the director of the UNIVEN Mal-ED site. The Mal-ED study cohort includes participants in the same villages as the ongoing WHIL project, allowing the two to benefit from data sharing. The data set that has been collected from the cohort of children is extremely rich including careful assessment of incidence of diarrhea, etiologic analysis, intestinal function, genetic data, microbiome data, development data, detailed anthropometrics, and detailed socio-demographic data. The cohort includes approximately 200 children and plans are being made to follow them beyond the originally planned end-point of 24 months.

Dr. Pagsuyoin began the process of developing the ABM by creating a model describing relevant data points and their predicted relationshi ps. (See Figure 7) With her team, she also created a map with the locations of the households identified in the original WHIL census and their water sources. (See Figure 8) This visualization, in the software program, allows for an easy-to-understand animation demonstrating the
relationships between households, water collection site, development of diarrhea, and reduction in child stature. (See Figure 8) Subsequently, with data collected from field studies (including water quality data, anthropometric data, water treatment frequency rates) and from the literature (impacts of diarrheal disease on child growth), the WHIL-ABM was created and refined with input from faculty at both universities.

Figure 8: Map depicting communities modeled in the WHIL-ABM

In other pilot grant activities, Drs. Learmonth and Pagsuyoin led a workshop at UNIVEN in agent-based modeling to build capacity and to elicit feedback on the preliminary model from UNIVEN faculty. In addition, a multi-disciplinary review panel made up of a prominent public health physician, a civil engineer, and a modeler with international experience evaluated the preliminary model in August 2011. Their report highlighted the success of the trans-disciplinary structure, the importance of the existing datasets from Mal-Ed and WHIL, and the opportunities provided by the on-going WHIL projects, especially the ceramic water filter program. They also made suggestions for future directions which will be discussed in the potential projects section.

In collaboration with her team, Dr. Pagsuyoin has produced three manuscripts based on the experiences with the WHIL-ABM. The first, “Novel Application of Agent-Based Modeling in Evaluating Global Health Programmes,” is a review of agent-based modeling in global health and has been submitted to International Journal of Epidemiology. The second, “Development of a Spatial and Temporal Agent-based Model for Studying Water and Health Relationships: the Case Study of Two Villages in Limpopo Province, South Africa” describes the development of the WHIL-ABM and has been submitted to Journal of Artificial Societies and Social Simulation. A third manuscript entitled, “Evaluating the Impact of Hygiene and Water Quality Interventions Using Agent-based Modeling and Simulation,” which describes the statistical evaluation of potential interventions to impact ECD in the WHIL-ABM is complete but has not yet been submitted.

At the end of her post-doctoral year with the WHIL-ABM, Dr. Pagsuyoin successfully competed for a tenure-track position in civil engineering at the University of Waterloo in Canada. We see this as another success of the WHIL-ABM, the launching of a new faculty career in global health.

In summary, the Framework Program at UVa has permitted the development of a sustained, trans-disciplinary and trans-institutional research group with strong ties to communities that struggle with a major public health challenge common to many communities in rural sub-Saharan Africa, poor access to drinking water and high burdens of ECD. Undergraduate, doctoral, and post-doctoral students
have all participated. Many have described how participation has “transformed” them and altered their career paths towards global engagement. Faculty members have produced new grant proposals and co-authored abstracts and manuscripts describing the process and the substance of the WHIL work. The senior administration of both institutions and the academic leadership of the schools and programs most involved in WHIL have indicated their support for this proposal based on WHIL’s synergies with their missions. (See letters of support.) We look forward to developing a comprehensive post-doctoral WHIL Innovation Fellowship to push the WHIL projects forward and, more importantly, to offer promising young global health leaders from the US and Southern Africa the opportunity to gain experience in cutting edge global health research and education with a particular focus on water and ECD. We expect that these individuals will multiply the investment in their training through their future contributions to global health research, education and innovation.

Overview of Proposed Training

The WHIL Innovation Fellowship sets forth three major objectives for its fellows consisting of skills-building, project development and completion, and portfolio development. Activities associated with the attainment of these objectives are listed beneath each objective below. See figure 9 for a timeline of activities over the five year cycle. Please refer to the key at the bottom of the figure to see which activities take place at which point in the fellowship year.

Recruitment will be undertaken each September for three positions. Two positions will be open for a 12-month period beginning in January, one for a US candidate and one for a UNIVEN candidate. An additional position will be available for a year-long fellowship beginning in May. These staggered start times will ensure that, after the first cohort, no fellow will be without peer mentorship from a fellow who has already had experience with the WHIL project.

Given expected numbers of applicants, it is predicted that there will be two UVa post-doctoral fellows and one from UNIVEN in the first year. However, based on the availability and quality of applicants from each institution, the fellow selected for the May start date could be switched to UNIVEN. We expect to train a total of 12 post-doctoral fellows, preferably six from each institution.

**Water and Health in Limpopo Fellow Recruitment and Activities**

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Figure 9: Timeline of activities over a five year period

a. Lab/advisor meeting, b. Fellows seminar, c. Presentation to Research Committee, d. Block of short courses, e. Water and Health Symposium in Limpopo, f. Case study research design, g. Data collection, h. Manuscript and grant preparation, i. Pilot teaching of case study
WHIL Innovation Fellowship Program Objectives and Activities:

1. **To build skills necessary to engage in innovative global health research collaborations.**
   a. **Short courses:** Each fellow will complete 34 contact hours of short courses.
      i. Introduction to Innovation and Community Engagement in Global and Rural Health Research (January and May; 8 contact hours - only take once) (Dillingham/Bessong/Netshandama/Richardson/Handler/Louis)
      ii. Introduction to Water and Health (January and May; 4 contact hours; Smith/Louis/Dillingham/Guerrant/Samie)
      iii. Workshop on simulation modeling and mobile data collection (May; 8 contact hours). (Dillingham/Learmonth/Sankaran)
      iv. Global health research ethics (January; 4 contact hours) (Baernholdt/Krizancic/Hagenmeier/Thompson-Heisterman)
      v. Global health grant writing (May; 6 contact hours) (Guerrant/Smith/Olmsted/Bessong)
      vi. Global health publication strategies including interdisciplinary publishing and strategies for negotiation of authorship (January; 4 contact hours) (Smith/Guerrant/Samie/Dillingham/Krizancic)
   b. **Weekly “lab” meetings with mentor:** Each fellow will pick a mentor within the first month of the fellowship. For mentors with weekly “lab” meetings (Dr. Guerrant, Professor Smith, Dr. Dillingham, Dr. Bessong), the fellow will be expected to attend the “lab” meeting of her/his group. An alternative schedule for weekly progress meetings will be established for other mentors and projects.
   c. **WHIL Seminar (bi-monthly):** Attended by all fellows, in person or through video-conferencing. The fellows, in conjunction with faculty mentors, will determine the relevant topics for journal club and invited faculty presentations. Journal club and faculty presentations will alternate. The journal club may be replaced with fellow manuscript workshop on an as-needed basis.
   d. **Research or Training Conferences:** Individual trainees and their research committee may deem it useful for the fellow to attend additional conferences. For example, the T32 training grants in infectious disease and in biodefense at UVa offer several regular clinical and research conferences at which fellows would be welcome. (See letter of support from Dr. Petri) As appropriate, other training programs will be asked to host fellows at their conferences.
   e. **Research in Progress Seminars:** Each fellow will present at least twice per year to a video-conferenced multi-disciplinary audience.
   f. **Individualized tutoring in Laboratory and/or Project Management:** Each fellow will define needed instruction with experienced laboratory and grant administrators, listed in Program Staff above.
   g. **Presentation of work to university and community stakeholders at annual UNIVEN/UVa Water and Health in Limpopo Symposium (July at UNIVEN)**
   h. **Submission of abstract and attendance at an international global health conference such as Consortium of Universities in Global Health/Global Health Education Consortium conference or the Public Health Association of South Africa.**
   i. **Develop and pilot a case study** based on research experiences for the Global Development Studies program at UVa and for Global Health Short Course to be developed at UNIVEN.
2. **To conduct an innovative, mentored global health research project in the context of the multi-disciplinary WHIL program.**
   a. Select a primary mentor within first month of fellowship.
   b. Develop a research question related to the Water and Health in Limpopo program within first month of fellowship.
   c. Form a three person research committee within first eight weeks of fellowship.
   d. Design a plan of study and research within first eight weeks of fellowship.
   e. Draft and submit at least one publication from work conducted during fellowship.
   f. Draft and submit at least one grant related to work conducted during fellowship.
   g. Report progress to research committee quarterly.
   h. Report progress/findings to stakeholders at Water and Health in Limpopo Symposium in July.

3. **To develop a portfolio of research and training outputs that will serve as a framework from which to develop individual efforts and as a resource for future fellows and other trainees.**
   a. Maintain a weekly on-line journal of bulleted activities.
   b. Provide quarterly progress reports for research committee and portfolio.
   c. Make available .pdf copies of manuscripts, case studies, grants, and other research and education outputs on shared, password-protected site.
   d. Respond in a timely fashion to future inquiries about publications and positions from Ms. Ballard.

**B4. Research committee responsibilities**

Each fellow will select three research committee members from the collective faculty group. One faculty member who is not on the WHIL faculty can be chosen, if the research plan requires it and the principal research mentor approves. The selection should span disciplines and institutions. At least one faculty from UVa and UNIVEN must be on each committee. The committee members must agree to meet at the beginning of the fellow’s year to develop the plan of study and then quarterly to review progress and provide evaluations. These meetings may take place with video or teleconferencing.

**B6. Program Evaluation**

The WHIL Innovation Fellowship’s evaluation will include metrics for individual fellows, of the fellowship program, and of the overall collaboration. **Metrics to assess the fellows will include:** number of publications related to research related to the program; number of grants submitted and awarded; position attained following the training year; learner evaluation of the case study prepared; and a 360 degree evaluation of the fellow by peers, community members, and faculty. **All metrics will be collected at the end of the training year.** Fellows will be asked to submit information on publications, grants, and positions for at least five years following the end of the training program. **Metrics to assess the fellowship program will include:** summary statistics collected from the individual fellow assessment as well as a qualitative assessment coordinated by Drs. Richardson, Krizancic, and Netshandama. These three faculty all have significant qualitative research expertise, and they will conduct semi-structured interviews after the first year with faculty, staff, and the post-docs at both universities to determine how successful we are at achieving a trans-disciplinary framework for conducting research and training. From the results of these interviews, they will develop an evaluation tool for future trainees and will make recommendations for improvement of the collaboration to the faculty team. We will also seek input from the advisory board during their annual meeting. They will review aggregate statistics on fellows and review the qualitative assessment in a de-identified fashion. **A formal evaluation of WHIL will also be completed.** The WHIL faculty group will provide annual summaries of research and training activities with an emphasis on defining best practices for engaged community research and training across cultures and disciplines. These summaries, coupled with opportunities for the next year, will be presented to the advisory board for review and recommendations.
B7. Potential Projects for WHIL Innovation Fellows

The WHIL collaboration provides rich opportunities for "out-of-the-box" projects that can integrate fellows into the research program rapidly as well as the potential for the development of new initiatives when fellows bring a unique perspective or interest. Three WHIL projects offer particularly good opportunities for "tweaking." They all have potential for transformation through small, innovative and disruptive changes. The projects are: the WHIL-ABM, the ceramic water filter project, and off-shoots of the Mal-ED project. The three projects offer opportunities for innovation in policy, product delivery, and behavioral understanding respectively.

**WHIL-ABM:** The initial development of the WHIL-ABM, its validation, and preliminary verification have been completed. An external review committee for the WHIL-ABM provided helpful suggestions about priority areas for addition to the model. These included: additional inputs from the social and behavioral sciences, such as breast-feeding, leadership structures, and economic drivers in the community; incorporating hand hygiene and sanitation practices; and collecting climatological data. They also recommended enhancing the model, so that it could more easily evaluate multiple, coincident interventions. With the growing availability of wireless data collection devices, the speed and ease with which quantitative data can be collected in the field has greatly improved and allows for efficient incorporation into the ABM, perhaps iteratively in real time. In addition, with the addition of four new faculty members with expertise in the social and behavioral sciences, we have new opportunities to collect qualitative and ethnographic data. (Krizancic; Handler; Thompson-Heisterman; Hagenmeier) Improving the WHIL-ABM will produce an important deliverable, a tool that can suggest which strategies might reduce ECD fastest and which allows for more informed intervention design. Once an intervention (or interventions) is selected and implemented, periodic data collection will confirm or contradict the WHIL-ABM. The WHIL-ABM can then be refined and tuned in light of these data. This continuous data collection and refinement of the WHIL-ABM is an innovative use of this method and can contribute to training multiple postdoctoral investigator, even those not previously involved in global health research, as well as informing policy-makers outside of academe.

**The Mukondeni Ceramic Water Filter Factory:** Since 1998, Potters for Peace, an independent, non-profit, international network of potters concerned with peace and justice issues, has been teaching communities to manufacture and distribute their low-tech, nano-silver-impregnated ceramic water filters that retail for $5 to $20. They can be manufactured primarily with local materials (clay and sawdust) and labor. Silver nanoparticles (zero-valent silver particles with a mean diameter ~25 nm) embedded in the porous ceramic matrix act to deactivate pathogens in the water. Since clay pots are often used as storage containers for water, it is a socially acceptable technology that can work year round in different climates. It does not impart an objectionable taste to the treated water. It is designed to remove both turbidity and pathogens. The clay filters are placed on top of 5-gallon plastic containers. Water is then poured into the filter pot and flows into the lower container where water can be accessed with a spigot (See Figure 10). Recently completed research indicates that these ceramic filters can effectively remove indicator coliform bacteria from water in both laboratory and field settings. (Oyanedel-Craver & Smith., 2008) (Kallman & Oyanedel-Craver, 2011) As described in the background, we have demonstrated that filters like those produced by Potters for Peace can reduce days of diarrhea in HIV+ individuals in Limpopo. The filters used in the study were imported from the US to South Africa.

![Figure 90: An advertisement developed for ceramic water filters by Potters for Peace.](image)

Based on the positive health impacts and surveys indicating consumer interest in the region, we constructed a small ceramic water filter factory in partnership with a women's pottery cooperative in the summer of 2011. We did this with technical guidance from Potters for Peace and another non-governmental organization with filter factories in Hispaniola, FilterPure. As we further develop our Limpopo filter factory, we have the opportunity for extensive hypothesis testing in filter design, economic impact, social acceptance, life cycle assessment, and human health benefits. Furthermore, we can leverage our ongoing extensive health data collection efforts and agent-based modeling in our partner communities. We plan to distribute ceramic filters in our partner communities and to evaluate the human health benefits and social acceptance of this point-of-use water treatment technology. We also can investigate technological innovations in the field,
including partial or complete incorporation of copper nanoparticles into the filter to partially or completely replace the more-expensive silver nanoparticles. In addition, we plan to investigate the formation of zero-valent silver and copper surfaces on the ceramic matrix by applying the metal in solution as Ag+1 or Cu+2. During firing, the ionic silver and/or copper will be reduced to metallic silver/copper. This will substantially reduce the costs of the filters and simplify the manufacturing process. We expect that this project could support multiple WHIL Innovation Fellows exploring different aspects of this project ranging from specific product optimization, strategies for diffusion of the innovation, and novel studies evaluating health impacts and behavioral changes.

**Mal-ED:** Since late 2009 in our partner communities, the Mal-ED project has followed nearly 200 infants and their mothers from within days of the infants’ births. Field workers have collected and laboratory scientists have generated massive amounts of data about the children’s enteric function, their physical and cognitive growth, and their feeding patterns. Investigators have also evaluated mothers for reasoning capacity and for depression. Dr. Bessong is PI of the South Africa site and has authority to share data with WHIL Innovation Fellows. One issue of interest to the researchers at UNIVEN is the paucity of exclusive breast-feeding in the communities. Despite World Health Organization and South African Ministry of Health recommendations to breast feed exclusively for six months, none of the women whose babies have reached the age of six months have maintained exclusive breast-feeding. Amongst 122 women, the median duration of exclusive breast feeding was less than a month, 22 days. (personal communication) Both the Mal-ED and WHIL Innovation Fellowship teams see this observation as an ideal opportunity for interdisciplinary postdoctoral research, especially engaging scholars in the social sciences. If funded, we envision recruiting a post-doctoral anthropologist or ethnographer to inquire into the values and beliefs around breastfeeding, infant feeding, infancy, and maternity as well as the daily habits and practices of childcare. We imagine, for instance that there may be beliefs about the complementarity of some foods with breast milk as well as beliefs about the benefits of commercial food. We believe this project will appeal not only to researchers with an interest in medical anthropology but also to those working on the anthropology of food-ways, kinship and gender, and development. We expect the project to offer an opportunity not only to do basic socio-cultural research but also to apply anthropology to public policy through the collaborative development of recommendations for health education that would be meaningful and appropriate in Limpopo.