

## Research Article

# SolarSPELL health and education: global solutions with local impacts

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### Background

People in remote regions of developing nations have poor health outcomes with lower life expectancy and quality of life compared to higher-resourced areas. Remote communities typically lack stable access to high-quality health services. International humanitarian and development organizations including the United States Peace Corps have a longstanding history of delivering critical services. However, limited infrastructure including access to reliable electricity or internet restricts development workers' ability to provide effective health services to rural communities. Technology that enhances health education and service delivery in remote communities may improve health outcomes by impacting health knowledge and behavior.

### Methods

We partnered with U.S. Peace Corps to provide portable, solar-powered educational learning libraries (SolarSPELL; [www.solarspell.org](http://www.solarspell.org)) to remote communities in Pacific Island nations beginning in 2015 with Peace Corps Vanuatu educational volunteers and expanded in 2017 to include health volunteers (SolarSPELL Health). We conducted ethnographic observation and interviews with Vanuatu Peace Corps volunteers, Ministry of Health officials, and local residents of rural communities. We then conducted a comprehensive evidence review to identify current best practices for assessing and treating the most common conditions. We designed simple 2-page documents with assessment and treatment guidelines, reflecting evidence-based best practices, local culture, and resource availability. Each document was accompanied by a whiteboard video featuring simple drawings and narration designed for Peace Corps volunteers and local community members.

### Results

We report on findings from a pilot study focused on education for treating low back pain. Preliminary findings indicate significantly increased knowledge for Peace Corps volunteers ( $p < .01$ ), along with non-significantly increased self-efficacy scores ( $p = .169$ ). Interview data indicate high levels of satisfaction with the SolarSPELL technology, and widespread community utilization among Peace Corps volunteers and community residents.

### Conclusions

Tailored health content on the SolarSPELL platform increases knowledge about critical health topics among Peace Corps volunteers in under-resourced rural communities. The platform and education may have a positive impact on self-efficacy. However, high baseline levels of self-efficacy noted among Peace Corps volunteers may explain the failure to reach statistically significant increases in self-efficacy scores. This finding merits further study. Future work includes measuring individual and community health outcomes, quality of life, and cost benefit resulting from reductions in lost work and transfers for advanced health services. We plan continued implementation and content expansion of SolarSPELL Health in Vanuatu and additional global sites.

Life expectancy worldwide has increased with industrialization, rising from 32 years in 1800 to 48 years in 1950 to 70 years in 2012.<sup>1</sup> However, worldwide variation is significant, with starkly lower life expectancy in areas that lack stable access to high-quality evidence-based healthcare services as a result of geopolitical conflict, geography, economy, or infrastructure including reliable access to electricity or internet.<sup>2</sup> Lack of access to healthcare increases morbidity and mortality. The highest rates of newly diagnosed HIV, the majority of the world's teen births, 99% of maternal deaths, and half of all deaths in children under age five occur in impoverished and rural areas of developing nations where there are few doctors and limited health resources.<sup>3</sup>

People living in underserved areas of the world face the possibility of dying up to 36-years sooner than those in developed nations. Many premature deaths could be avoided through access to evidence-based health education. Since 1961, United States Peace Corps (USPC) volunteers have provided development interventions worldwide with a focus on education, health, and community resource development. In one prominent example, USPC community-based education interventions in Botswana reduced HIV transmission rates dramatically.<sup>4</sup> This case and others worldwide, have had significant impacts on health outcomes and life expectancy in areas lacking stable healthcare resources.<sup>5</sup>

In the past decade, e-health has become an increasingly prevalent component of healthcare education and delivery worldwide. In developed nations, electronic health records have become ubiquitous, and a majority of people in industrialized nations use the internet to search for health information. Studies show that e-health technologies for health education can improve health literacy and outcomes across a variety of populations.<sup>6</sup>

However, one overarching challenge and a contributing factor to poor health outcomes in underserved areas of the world is that over one billion people live without electricity, and more than four billion have no reliable access to the internet.<sup>7,8</sup>

The Republic of Vanuatu is located in the South Pacific, approximately 2200 miles northeast of Australia. Vanuatu comprises 83 remote islands in the South Pacific (61 inhabited). Most of these islands have no reliable source of electricity or internet connectivity. Vanuatu receives 5-13 feet of rain and experiences as many as 6 cyclones annually.<sup>9</sup> The population of Vanuatu is 280,000 with 12.5% (35,000) of the population residing in the capital city Port Vila. Life expectancy in Vanuatu is 70 years for males and 74 years for females, with the median population age 21.7 years. Vanuatu's health infrastructure includes two major referral hospitals (located in Port Vila and Luganville) and four provincial hospitals with 30 health centers and 97 dispensaries around the country.<sup>10</sup>

The USPC has served in Vanuatu since 1990. As of 2017, there were 76 USPC volunteers serving in Vanuatu, including 28 health volunteers and 48 education volunteers. USPC volunteers often have hours-long rides in small fishing boats, or small propeller planes to get to from the capital

city to their assigned island. Sometimes this is followed by a one to two hour-long hike to get from the coast of their island or the dirt airfield to the village in which they will live and serve for two years. USPC volunteers have limited access to health education resources, and therefore rely on the current practice of government distributed healthcare information in printed form. Sometimes this information is outdated. Constant high humidity and torrential rainstorms can render scarce paper resources unusable due to water damage and mold. When these healthcare informational resources are unavailable, it impedes the implementation of vital best practices and negatively impacts health outcomes.<sup>11</sup> When healthcare information is available, tailoring interventions to local healthcare workers, as well as patients, is best practice in low-income communities.<sup>12</sup> Increasing access to culturally relevant healthcare information has the potential to improve health outcomes for the people in Vanuatu and other remote, resource-limited locations of the world.

SolarSPELL is a portable, waterproof, solar-powered educational digital library. The SPELL is a "digital library in a box." The "library" is a 12" x 18" x 3" watertight clear-plastic case which houses a Raspberry Pi 3 Microcomputer, a 10W eco-worthy solar panel, a voltage regulator, and a 10,000mAh rechargeable battery. The Pi3 microcomputer emits a Wi-Fi signal and has a 64 GB micro secure digital (SD) memory card. It acts as an off-line server, hub, and virtual internet. The SPELL provides free connectivity for any smart device i.e., smartphones, tablets, or laptop computer within 50 yards.<sup>13</sup> When accessed via the offline Wi-Fi signal it appears similar to a website. This offline experience also allows for a safe distraction-free technological experience and can aid in internet readiness for the population when their ability to access the internet occurs. It is user-friendly, colorful, and inviting. SolarSPELL leverages smartphone technology that is ubiquitous worldwide, but underutilized due to limited internet connectivity and cost constraints associated with data use.

The SolarSPELL library is housed on an SD card that contains more than 10,000 journal articles, books, videos, teaching tools, and other resources.<sup>13</sup> There is local content for each of the countries that SolarSPELL partners, including videos with people native to the country. Content, such as English as a Second Language (ESL), math, science, the environment and climate change, is abundant. Information on agriculture, community development, and youth empowerment is also included. There is a reference section with dictionaries, encyclopedias, Wikipedia for Schools, and additional teaching and classroom resources. The SolarSPELL includes generalized content from the World Health Organization (WHO), along with national Ministry of Health content for the country of deployment. Information specific to the USPC, which was once only distributed in printed form, is now digitally accessible through this technology. A version of the SPELL is available online at [www.SolarSPELL.org](http://www.SolarSPELL.org). SolarSPELL is a collaboration between engineers and librarians at Arizona State University who helped curate the library content to build a generalized library with specialized content for specific regions.

Beginning in 2015, SolarSPELL began a collaboration with the USPC in Vanuatu. SolarSPELL was initially targeted to USPC volunteers in educational settings. Initially, there was only minimal healthcare content on the SolarSPELL. Content was focused on classroom and community education, as it was targeted to assist the USPC volunteers who serve specifically as educational volunteers. The SPELLs provide access to resources for use in the classrooms. In 2017, USPC Vanuatu requested an expansion of the SolarSPELL program to include health volunteers as well as education volunteers in order to incorporate SolarSPELL technology to use in the local village clinics with an increase in the healthcare content. SolarSPELL teamed with the ASU College of Nursing and Health Innovation to develop the evidence-based culturally relevant healthcare content of the SPELL, as well as expand the SolarSPELL project to include distributing SPELLs to the healthcare USPC volunteers. This project became known as SolarSPELL Health with an overall goal of improving health outcomes in resource limited areas of the world.

## METHODS

In this section we describe the longitudinal evolution of the SolarSPELL Health library content from the contextual groundwork to its delivery via a pilot implementation related to low back pain in Vanuatu. We report on measures conducted on the pilot implementation. The entirety of this work was conducted under ethics approval from the Arizona State University Institutional Review Board, which deemed the work to meet exempt status.

### HEALTH NEEDS ASSESSMENT

In order to grasp the needs of USPC health volunteers and communities in rural Vanuatu and ensure that SolarSPELL Health content would be relevant for the local population, we undertook an ethnographic community health needs assessment.<sup>14</sup> The assessment consisted of face-to-face meetings with USPC Vanuatu officials and volunteers, Ministry of Health officials, and participant observation in Port Vila and rural areas over 10 days in May 2017. Field notes detailed the health needs, culture of aging, dynamics of mental or physical deficits, language, identity, and the familial power structure. In addition, the team documented many problems common to developing nations, including poverty, lack of adequate sanitation, food and water insecurity, and low healthcare literacy as well as the impacts of globalization. During the observation period, Vanuatu experienced a cyclone, giving the SolarSPELL Health team an opportunity to observe infrastructure limitations, including limited transportation and communication opportunities for rural communities. This community health assessment helped to develop a list of the community's current healthcare needs.

The SolarSPELL team met with health officials at the Ministry of Health (MOH) of Vanuatu. The MOH is the country's governmental agency responsible for protecting and promoting public health and providing public health

services.<sup>15</sup> The MOH provides health information, medical supplies, and community health workers throughout the country. One document the MOH supplies community health workers is a printed Aid-Post manual. This is a resource guide for community healthcare workers and USPC volunteers to use at small aid stations in villages where basic primary health needs are addressed. These manuals were updated in 2017 for the first time in ten years. There is an electronic portable document format (PDF) version of this manual available online.<sup>16</sup> The remote islands of Vanuatu have no electricity or internet access, so permission was obtained from the MOH to upload this new Aid-Post manual to the SPELL prior to initiation of the pilot project. This manual is now more freely and securely available in the community because it is digitally available on the SPELL.

Unstructured interviews with USPC officials, volunteers, and alumni in the Pacific region revealed that some individuals believe that illness is a "curse." Lack of formal education, low health literacy, and poor understanding of medication use are also problems impacting health and healthcare on these islands. One USPC volunteer recalled a patient report of taking antibiotics, "for a few days but then saving the rest to feed to the chickens when they get sick."

During the SolarSPELL Health team community assessment, women expressed concerns about childhood episodes of diarrhea and skin infections. Other areas of concern expressed by community members included causes and treatment of low back pain and the safety of birth control methods. They spoke of food sharing dynamics in the community. More complex issues were discussed including frustration with spousal infidelity, the power imbalance between men and women, and some whispered about their personal experiences with domestic violence.

Information obtained from the community health assessment and interviews in Vanuatu, coupled with data from the Vanuatu Ministry of Health, provided direction to decide on ten initial culturally relevant healthcare topics. The topics selected for primary focus were 1) hypertension, 2) vision screening, 3) skin infections (boils and abscess identification and treatment), 4) viral and bacterial infections and the responsible use of antibiotics, 5) hand washing, 6) back pain prevention and non-pharmacologic treatment, 7) diabetes prevention and management, 8) obesity, 9) family planning and sexually transmitted infections (STIs), and 10) domestic violence. Educational materials related to these topics were, therefore, prioritized for inclusion in the SolarSPELL Health library.

### PILOT PROJECT

One example of the effectiveness of this process is the module on non-pharmacologic treatment of back pain. Most rural residents of Vanuatu practice subsistence farming. Low back pain is a frequent occurrence with the physical implications of the farming lifestyle and poses a threat to the well-being of the entire family unit and community when farming practices are interrupted due to back pain and injury. Research-based best practices include the use of pain relievers and muscle relaxants to treat low back pain, in addition to rest, targeted exercise, and chiropractic ma-

nipulation. However, our needs assessment identified that medications are not typically available in rural areas, and health workers are not trained in chiropractic manipulation or therapeutic exercise.

#### EVIDENCE-INFORMED PDF EDUCATIONAL TOOL DEVELOPMENT

Following the local needs assessment in Vanuatu, the SolarSPELL Health team completed a comprehensive evidence review related to low back pain assessment and treatment in order to develop locally relevant content for the library. We conducted an exhaustive multi-database search for recent content related to low back pain and used a rapid critical appraisal tool to evaluate the strength and relevance of the evidence. A “two-pager” informational document was created with the current EBP guidelines for low back pain treatment as well as current practice in Vanuatu. This two-pager was designed to provide information related to disease processes, diagnosis, and treatment for use by USPC volunteers and community healthcare workers. The two-pager was designed to target USPC volunteers and lay community health workers with basic first aid training but no formal health education. The two-pager was targeted at an 8<sup>th</sup> grade reading level, though some necessary terms increased the measured reading level for the documents. For example, the Flesh-Kincaid grade level of the low back pain two-pager is 10.6, noting that a few critical elements of medical terminology raised the grade level of the document above our target grade level of 8.

We adapted the clinical practice guideline on noninvasive treatments for acute, subacute, and chronic low back pain from the American College of Physicians within the context of Vanuatu’s inherent medical resource constraint.<sup>17</sup> While the guideline informed what to do medically, it did not expand upon how to implement in a resource-constrained environment. Therefore, we examined the guideline to identify specific therapies that would be possible to implement in the rural Vanuatu settings. We included an assessment for red flag indicators that prompt need for advanced medical intervention, methods of self-treatment including continued activity, heat application, self-myofascial release, core strengthening, strain-counter-strain therapy, and osteopathic self-realignment.<sup>18–23</sup>

One guideline recommendation suggests the use of short-term muscle relaxants as a second-line therapy (> 7 days) in acute (< 3-month duration) low back pain. While muscle relaxants are not available in the field, kava, a botanical used for spiritual, cultural and medicinal practices by the indigenous people for over 2000 years has documented muscle relaxant qualities. A joint review of evidence on kava safety, dosing, and potential toxicity was performed by the Food and Agriculture Organization of the United Nations and the WHO.<sup>24</sup> Their findings were synthesized with current best evidence to guide safety recommendation for kava as a short-term muscle relaxant. Education was provided on the consequences of unsafe kava use including liver cirrhosis, liver failure, treatment failure in patients with HIV or tuberculosis, and harm to unborn children when used by pregnant women.<sup>25,26</sup> Kava was not

supplied or administered during this study. Although the Food and Drug Administration (FDA) has posted warnings regarding potential liver toxicity related to kava, it remains a legal, although unregulated dietary supplement in the U.S.<sup>27</sup> There are no restrictions on kava use among USPC volunteers as it is seen as a replacement for alcohol and a bonding mechanism between the volunteers and the native population. The SolarSPELL Health low back pain module, therefore, incorporated content related to exercise, self-care, and use of kava without including therapies that are not available to the target population.

#### WHITEBOARD VIDEO EDUCATIONAL TOOL DEVELOPMENT

Interviews with past and current USPC volunteers in Vanuatu, as well as observation of community members currently using the SolarSPELL, revealed that community members prefer to watch videos on the SPELL. Therefore, we produced a short white-board video to accompany each two-pager for SolarSPELL Health. Whereas the two-pager was primarily designed for use by USPC volunteers and community health workers, the video was designed to be simple and humorous for lay community members to watch.

The whiteboard video features simple hand-drawn stick-figures “acting out” to a recorded narration. For example, the video on skin infections shows a stick figure who develops a skin infection followed by the stick-figure taking medicine. Finally, the stick-figure no longer has a skin infection. The goal is that by simply watching the video, even without the narration, it is understood that the medication is needed to cure the skin infection. The target audiences for the whiteboard videos are the local community members of all ages. They are designed to teach needed healthcare information through simple entertaining concepts. The stick-figure white board video approach allows for universal application without concern about skin tone, body shape, or other visual impacts that might potentially disenfranchise a target population. The videos are recorded in English. The goal is for these videos to be translated into indigenous languages. For example, future iterations for Vanuatu will include Bislama translation with translation to other languages as appropriate for other regional implementation projects.

A template was designed to create and produce whiteboard videos and accompanying informational two-page documents (in PDF form) to upload onto the SPELL. The information is delivered in a user friendly, concise, and culturally sensitive way. The first four topics to be piloted are hypertension, skin infections, hand washing, and back pain treatment. These topics were chosen from the initial list of topics due to perceived low risk of encountering significant cultural barriers and potential to incite gender-specific violence. The most complex topics, including domestic violence, will be addressed in the future when the team has a more sophisticated understanding of security implications for vulnerable populations.

## FIELD DEPLOYMENT AND EVALUATION

USPC volunteers in Vanuatu underwent a training session on the low back pain module as part of their orientation to the SolarSPELL technology. Prior to the training session, USPC volunteers took pre-test knowledge and self-efficacy assessments. Assessments were repeated following the training at the same session, then qualitative follow-up >30 days post-training after they had returned to the field and began using the SolarSPELL device with SolarSPELL Health modules. This assessment scheme accounted for the challenges with lack of regular field communication with USPC volunteers in remote areas that precluded the ability to conduct follow-up quantitative assessment.

Surveys included the New General Self-Efficacy Scale (NGS-ES) which is reliable for self-efficacy across applications<sup>28</sup> and the Low Back Pain Knowledge Questionnaire (LKQ), which is specific, sensitive, and validated for healthcare knowledge. Paired two-tailed t-tests were used to evaluate bilateral distribution, and significance for both instruments.<sup>29</sup> The 16-item LKQ is validated for use in healthcare professionals and patients, making it ideal to assess knowledge in USPC volunteers who serve in a paraprofessional healthcare role, often without formal healthcare training. Moreover, these tools are ideal for future study beyond USPC volunteer populations, as they are valid with a wide range of professional, paraprofessional, and lay audiences.

## RESULTS

We administered knowledge (LKQ) and self-efficacy (NGS-ES) assessments to 23 USPC volunteers undergoing SolarSPELL training with focused low back pain assessment and treatment in Vanuatu in December 2017. Pre-test and post-test means for low back pain knowledge using the LKQ were 15.83 (SD 4.32) and 20.65 (SD 2.48) respectively,  $p < .01$ . Pre-test and post-test means for self-efficacy (NGS-ES) showed nonsignificant change from 33.57 (SD 4.32) pre-test to 34.74 (SD 4.13),  $p = .17$ .

In addition to survey findings, we had an incidental finding of identifying signs of kava toxicity and liver impairment among USPC volunteers during the didactic portion of the SolarSPELL Health training. Kava is cleared through the cytochrome P450 system through the CYP2E1 allele. Genetic deficiencies in this metabolic pathway are relatively infrequent in the general population but can cause liver failure and event death in affected individuals.<sup>30</sup>

Intended outcomes included achieving statistically significant increases in knowledge, and indications for stable levels of self-efficacy among USPC volunteers. Based on observational and informal interview data from the SolarSPELL intervention session, USPC health and education volunteers were enthusiastic at the intervention. Anecdotal reports from the field after more than 30 days of SolarSPELL use indicates acceptance of role expansion to include evidence-based health interventions. Evidence of successful use of SSH by the indigenous population in Vanuatu was evident three months post intervention, with multiple USPC volunteers sharing photos of rural villagers using the

SolarSPELL library. Proof of concept for SSH was achieved. Unintended outcomes included enthusiastic adoption of kava safety guidance by USPC volunteers, and Vanuatu MOH staff alike.

## DISCUSSION

The use of localized health information delivered in a digital format can have significant impacts to improve healthcare delivery and health outcomes for people in developing regions globally. The example of the SolarSPELL Health library as a tool for USPC volunteers and their local counterparts in Vanuatu illustrates the value of capturing local needs in order to develop an effective tool for health information and education.

The example of kava provides a poignant illustration of the importance of information localization for health education. Kava's ubiquitous use conveys a sense of inherent safety in Vanuatu. Therefore, culturally relevant evidence-based information on selection, preparation and appropriate use of kava as a short-term muscle relaxant was provided. Interestingly, neither USPC Vanuatu volunteers nor the clinic nurses with which we shared the modules knew of the hazards associated with kava misuse. At the time of this study there was no protocol for kava use screening in primary care. As a result of this intervention, the nurses stated uniformly they were going to implement screening mechanisms in their clinics. Additionally, several USPC Vanuatu volunteers upon reading the kava warning within the module, stopped the module and reflexively communicated the warnings to other USPC Vanuatu volunteers who were not participating in the research. Three individuals recognized symptoms of kava toxicity in themselves or others, which prompted them to seek treatment. Since no identifying information was collected, there is no opportunity for follow-up. However, this experience highlights the need to critically evaluate indigenous health practices to incorporate into culturally relevant health education materials.

Future work includes development of additional SolarSPELL Health PDF and video modules with study of larger groups including USPC and other lay health volunteers globally, as well as indigenous populations in Vanuatu and additional global sites. Our study findings provided proof of concept for additional planned SolarSPELL Health implementation in developing regions of the Pacific, East Africa, and South America as a tool to improve healthcare delivery and health outcomes. In addition to site expansion, we plan to expand impact evaluations by studying clinical outcomes at individual and community health levels, quality of life, and cost benefit resulting from reductions in lost work and transfers for advanced health services in capital cities.

## CONCLUSIONS

In this exploratory study, SolarSPELL Health provided an effective, reproducible, and inexpensive platform for delivery of a brief, evidence-based, and culturally relevant public health module. The data revealed evidence of statistically significant increases in knowledge among participants as

a proximal outcome measure. Follow-up at three-months post intervention suggests integrated adoption by USPC volunteers and expansion of use to include indigenous persons. Although the SolarSPELL Health intervention did not achieve statistically significant improvement in USPC volunteer self-efficacy, this may be explained in part by the small sample size (N=23), and/or the unusually high levels of baseline self-efficacy historically present in USPC volunteers as a population.<sup>31</sup> More in-depth analyses are needed to specifically determine the needs of local populations in developing regions with longitudinal assessment of informational interventions including SolarSPELL.

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#### AUTHORSHIP CONTRIBUTIONS

All authors contributed to the study and writing of the manuscript.

#### COMPETING INTERESTS

The authors completed the Unified Competing Interest form at <http://www.icmje.org/disclosure-of-interest/> (available upon request from the corresponding author) and declare no conflicts of interest.

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