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Using Pictorial Action Instructions to Train Low-Literacy Adults to Construct a Basic Humanitarian Engineering Project

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USING PICTORIAL ACTION INSTRUCTIONS TO TRAIN LOW-LITERACY ADULTS TO

CONSTRUCT A BASIC HUMANITARIAN ENGINEERING PROJECT

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Abstract

Low- and middle-income countries (LMICs) are often disproportionately faced with environmental hazards, which can cause adverse health outcomes. Although humanitarian engineering projects have been created to mitigate these hazards, LMICs are also frequently impacted by literacy deficits, creating a barrier in training low-literacy individuals to construct these projects. The purpose of this dissertation was to develop, refine, and test the usability of pictorial action instructions (PAI) in training low-literacy individuals to construct a humanitarian engineering project. A concept analysis was completed, including the creation of an operational definition, for "lay worker health literacy." This analysis and definition set a foundation for equipping non-health professionals with methods for applying basic health interventions to promote health at individual and community levels. Next, PAI were developed using best practice guidelines and expert review. A feasibility study was conducted with five low-literacy adults to assess how the instructions were interpreted and could be improved; revisions were then made accordingly. The final PAI were used in a 60-participant randomized control trial in rural Guatemala, which compared the PAI-based training to demonstration-only training for constructing a solar bottle bulb. Both methods were evaluated for construction effectiveness and efficiency, as well as user satisfaction and self-efficacy levels. Significantly better results were noted for effectiveness and self-efficacy in the intervention group. Efficiency was not significantly different between the two groups, and a ceiling effect was noted for user satisfaction. Overall, the process used to develop and refine the PAI resulted in training instructions that increased construction effectiveness and self-efficacy among low-literacy individuals. Further studies are needed to test these PAI among low-literacy individuals in different contexts, as well as to develop and test PAI for other humanitarian engineering projects.

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Finally, I owe my eternal gratitude to my family for their unwavering support during this academic endeavor. Through my seemingly endless hours of typing, late nights spent swearing at the computer, and countless social activities that I had to miss, you all were patient, understanding, and supportive, well beyond the logical bounds of acceptance and encouragement. I hope to find a way to express my unconditional love for you each, and hopefully someday return the favor.

Dedication

"Here's to the crazy ones…the misfits...the rebels...the ones who see the world differently… They change things. They push the human race forward… The people who are crazy enough to believe they can change the world are the ones who do" (Siltanen, 2011).

To my amazing son, Zion, I dedicate my dissertation and my life. Finding each other has been one of the single greatest surprises and gifts that I have ever received. I hope you always hold on to your kind heart, your adventurous spirit, your fearless sense of self, your overwhelming optimism, and your deep desire to push the human race forward. I have no doubt that you are just crazy enough to change the world! You can do anything you set your mind to (but first, let's focus on you finishing the 5th grade).

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Chapter 1: Introduction

This research was conducted to develop, refine, and assess a method of training low-literacy individuals to construct a humanitarian engineering project that can improve environmental health in LMICs. The rationale for research, gaps in the literature, aims of the dissertation, and descriptions of the manuscripts are included in this chapter.

Rationale for Research

Health in low- and middle-income countries (LMICs) is disproportionally affected by environmental hazards, such as unsafe water, poor sanitation, indoor smoke inhalation, and unintentional acute poisoning. These hazards can lead to adverse health effects, such as diarrhea and respiratory issues, and are responsible for millions of deaths annually (Health and Environmental Linkages Initiative [HELI], 2016). Basic technologies to help people and promote social justice, known as humanitarian engineering projects (Passino, 2015), have been designed to mitigate these hazards. However, widespread literacy deficits often found in underserved areas can present barriers to training low-literacy individuals to construct these projects.

The scope of the problem is immense, as 38% of the independent economies in the world are identified as LMICs (World Bank, 2016b). With 10.7% of the world's population falling below the international poverty line of $1.90 a day, more than 767 million people are at risk for inadequate environmental conditions (World Bank, 2013). In LMICs, the overall burden of disease from environmental factors is 15 times higher than developed countries (WHO, 2006b), and often there are fewer than 2.5 health care professionals per 1000 population (WHO, 2006a) to help manage health concerns. A portion of this health worker deficit is covered by lay workers, but considering overall literacy rates in LMICs range from 57-74% and that these percentages decrease sharply in rural regions of these countries (World Bank, 2016a), many lay

workers lack basic literacy skills to attain the training necessary to improve health conditions. Therefore, training methods must be adapted to expand access to these individuals.

The focus must be dual: the factors that indicate a need for intervention, and best practice approaches to mitigate the problems. This research is based on a strong understanding of three factors found in LMICs: environmental hazards, lack of access to humanitarian engineering projects, and low literacy rates, all of which increase the risk for negative health outcomes. The research also focuses on using pictorial action instructions (PAI) to address these factors and mitigate negative health outcomes. Each factor, and an appropriate intervention, must be addressed.

Environmental hazards. Environmental factors are responsible for 25-35% of global deaths and burden of disease each year (HELI, 2016). LMICs are disproportionally affected by injuries and infections associated with environmental hazards, which can markedly increase morbidity and mortality in the most underserved regions in the world. Annually, diarrheal disease from unsafe water and poor sanitation are estimated to kill 1.7 million people, and respiratory disease from indoor smoke inhalation is responsible for 1.6 million deaths. Many other hazards, such as climate change and toxic substances, are present as well.

Although many hazards are significant, some are difficult for individuals to control at the household level. For example, in areas where sanitation systems are not well-established, in-home interventions may be thwarted by poor sanitation practices of neighbors, particularly in terms of contaminated shared water sources. Other hazards, however, can be addressed at the household level, such as indoor smoke inhalation (HELI, 2016), which can lead to tuberculosis (Pokhrel et al., 2010), chemical pneumonia (Mills, 2016), and asthma (Lam et al., 2012). Kerosene lamps used in the home account for more than 60% of residential kerosene

consumption and emit pure black carbon, carcinogenic fine particulates, carbon monoxide, nitric oxide, and sulfur dioxide (Lam et al., 2012). Health risks for these lamps also include acute poisoning (Lam, 2014) as well as explosions and burns (Maritz, Wallis, Van Der Merwe & Nel, 2012). Interventions to decrease this hazard can be easily implemented at individual and household levels.

Humanitarian engineering. Interventions to offset these environmental hazards are developed through humanitarian engineering, focused on creating technologies to promote human welfare in underserved communities (Ohio State University, 2016).

Engineering projects. The largest repository of humanitarian engineering concepts is housed by Engineering for Change (2016), a prominent organization in this field. More than 300 prototypes and projects, as well as implementation studies for some projects, are available online, including safe water storage containers (Doocy et al., 2006), hand-washing stations (Biran, 2011), and food dehydrators (Janjai, 2012; Pardhi & Bhagoria, 2013). Many studies focus on interventions to decrease indoor smoke inhalation, including improved basic cooking stoves, and solar interventions in areas without electrification (Baldwin, Brass, Carley & MacLean, 2014; Pilishvili et al., 2016; Smith et al., 2011).

Solar bottle bulb. One such intervention that meets an overwhelming need is the solar bottle bulb (Liters of Light, 2016). Among the 1.2 billion people in LMICs who do not have access to electricity in their homes (World Energy Outlook, 2016), more than 80% rely on kerosene-based lamps (Furukawa, 2012), collectively consuming approximately 77 billion liters of kerosene per year (International Energy Agency, 2006). Kerosene lamps pose serious risks for burns and fire, as well as significantly contribute to respiratory disease (Pokhrel et al., 2010). Use of solar-powered lights can provide a safer low-energy option (International Energy Agency,

2006), and is projected to decrease kerosene demands by 97% by 2030 (Lam, 2014).

Unfortunately, access to materials to create solar panels is still limited in remote areas, and

transportation for supplies may be cost prohibitive.

An alternative to traditional solar lighting, based on the principles of light refraction, is

the solar bottle bulb. It is made from mostly recycled materials, costs less than US$1 to make,

can amplify sunlight to mimic a 55-watt bulb (Kuo, 2017), provides ample light for a 40-square-

meter space such as a living area or classroom (Liter of Light, 2012), and is environmentally

sustainable (Wang et al., 2014). However, even this simple project is often introduced and

constructed by foreign volunteers on short-term development trips, which can undercut

competing local laborers, lead to dependency, and decrease sustainability (Guttentag, 2009).

Barriers to projects. Although evidence indicates that these projects can address

environmental hazards, there are two main challenges. First, in many LMICs there is uncertainty

regarding supply availability in resource-poor regions, eliminating access to projects that require

somewhat advanced technology, such as solar panels. As a result, there is often sluggish

adoption of technologies due to unfamiliarity, lack of access to construction materials, and cost.

While many projects are cost prohibitive for local individuals in LMICs, projects that can be

constructed with basic training and reasonably-attainable materials are cheaper, and are much

more likely to be implemented (Kuo, 2017). Second, databases for many humanitarian

engineering projects are present online, through groups such as Engineering for Change (2016).

However, the majority of instructions are text-based, limiting use by low-literacy individuals.

Additionally, while video options are also available for some projects, nearly 33% of the world

lacks mobile broadband or Wi-Fi and the majority of the 4.8 billion people without reliable

internet live in LMICs (Dobush, 2015), often making this content inaccessible to those with the

greatest need for these projects.

Literacy deficits. Many areas disproportionately affected by environmental hazards are also disadvantaged by widespread literacy deficits (Global Education Fund, 2016). This can create a barrier for training local individuals to implement these projects, as many instructions are heavily text-based. Functional reading literacy is generally attained through completion of education through a sixth grade level (UNESCO, 2009). However, 65 million lower-secondary-aged children are currently out of school, including nearly 49% of children in rural regions (UNICEF, 2014). The majority of these children are in LMICs, where overall literacy rates still only range from 57-74% (World Bank, 2016a).

Another contributing factor associated with low literacy in rural areas of LMICs is that less than 40% of those in these environments have access to electricity (World Bank, 2014). Availability of light within a home or school creates an indoor atmosphere that promotes students' learning and reading. A positive correlation, greater than 66%, exists between electricity consumption per capita and the education index in a study of 210 countries (Kanagawa & Nakata, 2008). Furthermore, the introduction of solar lights in schools in LMICs has nearly doubled primary and secondary school completion rates, led to increased scores on national examinations, and increased attendance rates (UNDESA, 2014).

Pictorial action instructions. An evidence-based method for addressing literacy barriers in training is the use of pictorial action instructions (PAIs) (Browder, Wood, Thompson & Ribuffo, 2014; CDC, 2010; Haaland, Akogun & Oladepo, 2001; Philips & Vollmer, 2012; Shah, Khan, Maqsood & Khan, 2015; Watkins, 2014). PAIs use a series of sequential pictures to convey information; this utilizes one's visual literacy, or how visual input is translated into understanding and used to communicate ideas (Eilam, 2012), as opposed to text-based literacy.

Although no large-scale studies were identified to test pictorial action diagram use in assembly instructions, similar findings support a high likelihood that the method could be successful in such an application. Kripalani et al. (2007) found that, among 209 low-literacy participants who used pictorial action instructions to complete each step in medication administration, 92% indicated that this method was easy to understand, and 94% stated that the use of pictorial instructions improved their adherence to the instructions in administration. Phillips and Vollmer (2012), on the other hand, focused specifically on assembly instructions, but conducted a small-scale study using only three participants who each completed five sequential steps. Although step sequencing was easily followed by all participants using the pictorial instructions, the sample size was too small to ensure applicability on a larger scale. Furthermore, Clements and Norton (2004) conducted a usability study with 22 participants to compare pictorial action instructions to traditional text-based instructions for completing a multi-step task. Their findings indicated statistically significant increases in the accuracy rates and decreases in project completion times for the group with the pictorial instructions. To ensure the validity of these marked differences in instructional approach, a larger study would need to be conducted.

The use of pictorial action instructions for low-literacy individuals has been incorporated as best practice by the CDC (2009) as well as the Robert Wood Johnson Foundation (Cowgill & Bolek, 2003). Furthermore, there are best practice guidelines to follow within the use of pictorial action instructions. The most frequently used guidelines for the inclusion of objects in these instructions come from the work of Schumacher (2007), who found that optimal comprehension was present when illustrations used simple line drawing with no shading. Also, instructions are easiest to follow when the vantage point remains consistent between steps, unless intentionally

emphasizing a need to shift perspectives. Finally, Schumacher's (2007) findings state that comprehension is best when the size of the objects does not change from frame to frame, and the only object that varies is the one of focus. Meanwhile, Haaland et al. (2001) have conducted multiple studies in various LMICs to identify best practices for in the inclusion of people in pictorial action instructions. Their main finding was related to the importance of including some semblance of the local dress or architecture within the pictures, while keeping details to a minimum, to create the simplest form that is relatable to those who will use the instructions.

By implementing humanitarian engineering projects to mitigate environmental hazards, and using PAI to train low-literacy individual to construct these projects, it is possible to evaluate the usability of this instructional approach. The use of PAI potentially allows broader access to information for those who most need these interventions, empowers low-literacy individuals, and promotes the sustainability and scalability of such projects in underserved regions.

Gaps in the Literature

The first gap identified in a 2016 systematic internet search and literature review was the absence of an operational definition for "lay worker health literacy." Although the concepts of "lay worker" and "health literacy" each existed separately, the combined concept of "lay worker health literacy" had not yet been established (Cadman, 2017). This concept provides a foundation for articulating the importance of equipping non-health professionals with the skills and knowledge to apply basic health interventions that promote health at individual and community levels.

The other major gap in the literature was a lack of connection between established problems and established solutions in managing health concerns associated with environmental hazards in LMICs. The problems evident in the literature include the detrimental affect

environmental hazards have on health and literacy deficits that can present barriers in training low-literacy individuals to address these hazards. The evidence-based solutions in the literature include humanitarian engineering interventions designed to mitigate these hazards, and the use of PAI to train low-literacy individuals. However, there has been no formal application of PAI to train low-literacy individuals in LMICs to create basic humanitarian engineering projects. Applications of PAI to train low-literacy individuals, found in the literature, primarily focused on medication administration (Kripalani et al., 2007), toy assembly (Phillips & Vollmer, 2012), and safety procedures (Cowgill & Bolek, 2003).

Aim of the Dissertation Project

The aim of this dissertation was to develop, refine, and test the usability of pictorial action instructions (PAI) in training low-literacy individuals to construct a humanitarian engineering project. This aim has three components: concept analysis, PAI development, and usability testing. The implications of developing usable PAI for this purpose involve reducing environmental health hazards in LMICs.

Concept analysis. First, the concept of "lay worker health literacy" was analyzed and an operational definition was provided. The aim of this analysis is to provide a clear understanding of the concept of lay worker health literacy. The operational definition provides a formal understanding of what is meant by equipping non-health professionals with the necessary tools to apply interventions that promote health. As such, this concept analysis and operational definition may be beneficial to those training lay workers as well as those developing training materials.

PAI development. Based on notable literacy deficits in many LMICs, training materials used to explain construction interventions that promote health need to be adapted for low-literacy individuals. Considering this, a specific humanitarian project, the solar bottle bulb, was selected

as a health promotion intervention, and PAI were developed for constructing the project. The illustrations and text followed best practice guidelines, and a feasibility study was conducted to determine the PAI clarity and ease-of-use in training low-literacy participants. Subsequent revisions made based on participant feedback resulted in PAI that were later used as the intervention in usability testing.

Usability testing. The PAI that were developed and revised through the feasibility study were then tested based on the conceptual framework of usability. The concept of usability assesses how well a product or method can be used by a specific population to enhance effectiveness, efficiency, and satisfaction of use (International Organization for Standardization, 1998). Self-efficacy was also assessed, as the personal belief an individual has about his or her own ability to complete a specific task (Bandura, 1977) is strongly associated with usability. A randomized control trial was conducted to establish how the usability of PAI compared to the usability of demonstration-only training, a common practice in LMICs (Guttentag, 2009). The study assessed usability among 60 low-literacy, community-based adults in rural Guatemala who each constructed a solar bottle bulb.

Implications

The implementation of usable PAI in training low-literacy individuals in LMICs to construct a solar bottle bulb can decrease or eliminate two common indoor environmental health hazards: kerosene lamps and dark, windowless homes (Lam, Smith, Gauthier & Bates, 2012). There are an estimated 2.8 billion biomass and kerosene users worldwide (Muindi et al., 2016), so access to usable instructions for the solar bottle bulb alone could potentially have a positive influence on health outcomes for more one third of the world's population. As construction of this project can be done primarily with found items, using basic hand tools, implementation can

be possible even in underserved areas where resources are scarce. Furthermore, the ability to develop usable PAI in training low-literacy individuals can also be applied to other basic humanitarian engineering projects to help mitigate other environmental hazards.

Manuscript Selection

This dissertation is comprised of three manuscripts focused on granting low-literacy individuals in LMICs access to interventions that can promote health within their homes and communities. The first manuscript articulates an application of picture-based instructions to improve comprehension in training, using visual literacy. The second manuscript explains the process of developing, revising, and testing picture-based instructions for use in training. The third manuscript tests the usability of these instructions when implemented in training low-literacy adults in a LMIC. Therefore, the first manuscript sets a foundation for the second manuscript, and the final product created and tested throughout the second manuscript became the intervention in the third manuscript.

Manuscript 1. The first manuscript is a concept analysis and operational definition for "lay worker health literacy." Within this analysis, picture-based instructions are indicated for training individuals to better understand health concepts, as training materials are often inappropriate based on either language or literacy levels. Recommended approaches to improving lay worker health literacy include picture-based teaching, pictograph comprehension tools, or other methods of verifying visual literacy. Articulating the concept of lay worker health literacy could improve the development of future training materials for individuals in LMICs.

Manuscript 2. The second manuscript focuses on developing, refining, and testing the usability of literacy-adapted training materials to construct a humanitarian engineering project designed to mitigate an environmental hazard. Specifically, PAI were developed, using best

practice guidelines and expert review, to illustrate how to construct a solar bottle bulb. Then, a feasibility study was conducted with five low-literacy adults to refine the PAI by improving clarity and comprehensibility, as well as to test the PAI's usability. This study resulted in a usable set of PAI for constructing a solar bottle bulb to be used as an intervention for further usability testing on a larger scale. The manuscript also provides recommended steps that can be taken to develop, refine, and test PAI for other humanitarian engineering projects in the future.

Manuscript 3. The final manuscript is a randomized control trial (RCT) that was conducted with low-literacy adults in rural Guatemala. The PAI that were developed, revised, and tested in the feasibility study served as the intervention in a RCT that compared usability of PAI-based training to usability of demonstration-only-based training for construction of a solar bottle bulb. Measurements for effectiveness, efficiency, user satisfaction, and self-efficacy were compared between the intervention and the control group. This study provided a data-driven assessment of the PAI as a training method, showing significant increases in construction accuracy and self-efficacy. Findings from this study raise opportunities for future research, both to test this PAI among low-literacy individuals in different contexts, as well as to develop and test PAI for other humanitarian engineering projects.

Chapter 2: Manuscript 1

Lay worker health literacy: A concept analysis and operational definition

The first manuscript is a concept analysis and operational definition for "lay worker health literacy." Within this analysis, picture-based instructions are indicated in training individuals to better understand health concepts since training materials are often inappropriate based on either language or literacy levels. Recommended approaches to improving lay worker health literacy include picture-based teaching, pictograph comprehension tools, or other methods of verifying visual literacy. Articulating the concept of lay worker health literacy could improve the development of future training materials for individuals in LMICs.

In October 2017, this manuscript was published in *Nursing Forum*, a peer-reviewed international journal for nurses and other health practitioners (Wiley, 2018). Copyright permission was obtained from the publisher to include this manuscript in this dissertation (Appendix A).

Cadman, K. P. (2017). Lay worker health literacy: A concept analysis and operational definition. *Nursing Forum, 52*(4), 348-356. doi:10.1111/nuf.12203

Abstract

The concept of lay worker health literacy is created by concurrently analyzing and synthesizing

two intersecting concepts: lay workers and health literacy. Articulation of this unique

intersection is the result of implementing a simplified Wilson's Concept Analysis Procedure.

This process incorporates the following components: a) selecting a concept, b) determining the

aims/purposes of analysis, c) identifying all uses of the concept, d) determining defining

attributes, e) identifying a model case, f) identifying borderline, related, contrary, and

illegitimate cases, g) identifying antecedents and consequences, and h) defining empirical

referents. Furthermore, as current literature provides no operational definition for lay worker

health literacy, one is created to contribute cohesion to the concept.

Introduction

The concept of lay worker health literacy currently has little structural backing; but as its implications could promote global health, further understanding of this concept is imperative. The concept of a lay worker (Harris et al., 2015; Lewin et al., 2010) and the concept of health literacy (Chin, 2011; Nutbeam, 2000) already exist, so the two will be analyzed concurrently to clarify the combined concept. This concept analysis will provide depth and context necessary for progressing towards mastery of this abstract idea, using a simplified Wilson's Concept Analysis Procedure (Walker & Avant, 2011). This procedure includes: a) selecting a concept, b) determining the aims/purposes of analysis, c) identifying all uses of the concept, d) determining defining attributes, e) identifying a model case, f) identifying borderline, related, contrary, and illegitimate cases, g) identifying antecedents and consequences, and h) defining empirical referents. Furthermore, as the literature currently provides no operational definition for lay worker health literacy, one is created in order to contribute cohesion to the concept.

Concept Selection

Rationale for selection. The World Health Organization (WHO) estimated that the global shortage of health workers exceeded seven million in 2013, and is anticipated to reach nearly 13 million by 2035 (World Health Organization [WHO], 2013a). Rural regions of developing nations are grossly underserved, compounded by fewer opportunities to receive health education in these regions. One solution presented in the literature is to increase the quantity and quality of lay workers to provide basic health services in these areas (Nkonki, Cliff, & Sanders, 2011).

A mixed methodology study was conducted in which a lack of proper educational materials was identified as a primary barrier to expanding the lay workforce (Cadman, 2013).

Materials, where present, were often inappropriate based on incongruent language and literacy levels. A subsequent literature review of studies conducted from 2011-2015 found ample evidence in support of using pictograph-based, easy-to-read (ETR) materials to increase health literacy. This author intends to test the efficacy of constructed ETR materials for increasing health literacy among lay workers in rural Guatemala. In order to assess the impact, more must first be understood about the concept of lay worker health literacy.

Aim of the concept analysis. The aim of this analysis is to provide a more comprehensive understanding of the concept of health literacy in lay workers. This understanding may be beneficial to those training lay workers as well as those creating materials to enhance health literacy. Through the process of identifying defining attributes, antecedents, consequences, and case examples, clarity will be brought to this concept and its applications. In addition, as no operational definition currently exists for lay worker health literacy, a secondary aim of this concept analysis will be to draw on preexisting definitions of aspects of the concept in order to address this gap in the literature.

Selection procedures. A systematic internet search was conducted from late January until early March 2016. The initial phase included a Google search and a YouTube search for the term "lay worker health literacy," both of which resulted in zero hits. When the search term was altered to "'lay worker' AND 'health literacy'" then Google produced 230 results including articles, training modules, and organization mission statements. A search of Google Scholar, using the same search term initially resulted in 23 articles, but after placing a date range of 2011-2016, 21 articles remained. Results included disciplines such as agriculture, education, communication, and health, but most findings were focused on either lay workers or health literacy, with brief mention of the other. Various interpretations emerged, but an overall

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understanding of the concept was achieved.

A search of "'lay worker' AND 'health literacy'" was then conducted in academic and professional databases in various fields, including: medicine, education, sociology, global health, and a multidisciplinary database. The search produced the following hits: PubMed Health (21), BioMed Central (3), The Educational Resources Information Center (ERIC, 1), SocINDEX (1), the WHO (39), and the Academic Search Premier (2). Then inclusion criteria were added: scholarly (peer-reviewed) journals, date range 2011-2016, and English language. The following exclusion criteria was also added: newspaper articles, book reviews. After removal of redundant findings, 46 articles remained. Upon reading all 46 abstracts only 22 were felt to contribute new information or aspects to the concept. One seminal piece from 2000 was included as well (Nutbeam, 2000).

As lay worker is an umbrella term including more than 60 different names for that role (Nkonki et al., 2011), searches containing other titles such as community health worker or promtor(a) may have resulted in more findings. For the purpose of this concept analysis, only literature using the verbiage "lay worker" was included. Furthermore, various forms of health literacy were identified, including functional, interactive, and critical (Nutbeam, 2000). Findings were not excluded for specifying a certain form of health literacy.

Concept Analysis

Use of the concept. As the exact phrase "lay worker health literacy" does not appear in literature, the concept was first broken into two parts, lay worker, and health literacy, to determine uses of each. Then implicit uses of the combined concept were addressed. A universal definition of a "lay worker" is not explicitly stated outside of various career lenses, but all uses conveys the common theme of an individual who has some training to perform a job, but has no

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formal professional certificate or degree. This is clarified further by the WHO as an individual who is performing health care delivery and interventions (WHO, 2013b). Other references for the use of "lay worker" were found for clergy, agriculture, the justice system, health, education, language translating services, and childcare.

The definition of "health literacy" is how well an individual can obtain, process, and understand basic health concepts and services in order to make appropriate health decisions (U.S. Department of Health and Human Services [HHS], 2016). This term includes a range of applications. As indicated by Nutbeam (2000), at the lowest end is functional health literacy, in which a person can understand health information such as directions on a prescription bottle. This level generally is associated with the understanding and regurgitation of facts or basic information. The next level is interactive, in which an individual can not only understand and regurgitate facts, but can also use developmental and personal skills to share this information with others. This level is also associated with providing care and education to others (Chinn, 2011). Finally, the highest level is critical health literacy. This level is associated with empowerment of individuals to critically think and synthesize health concepts based on the training they have received (Nutbeam, 2000).

Many articles implicitly reference the concept of lay worker health literacy. These references do not define this concept in broad terms, but instead offer specified functional meanings. The majority of these studies focused on lay worker health literacy in terms of functionality for a particular topic or interventions such as diabetes management (Henderson et al., 2013), tuberculosis care (Ritchie et al., 2016), smoking cessation (Harris et al., 2015), mental health (Mehrotra, Tripathi, & Elias, 2014), rheumatoid arthritis (Quinlan et al., 2013), or antiretroviral therapy (Lazarus, Safreed-Harmon, Nicholson, & Jaffar, 2014). Another major

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implied reference was the ability to provide health guidance to specific populations such as offender health in prison (South et al., 2014), screenings for rural native Hawaiian and Filipino women (Sentell, Cruz, Heo, & Braun, 2013), or Latino immigrants (Squires & O'Brien, 2012).

In summary, the definitions referring to the concept of lay worker health literacy were fragmented or implied. These definitions did, however, focus on common notions of an individual's ability to comprehend health-based information. The medical and global health fields further specified the ability of the individual to act on their comprehension in order to share health promotion with others.

Operational definition. An operational definition has been formed, by blending and articulating prior definitions in the literature regarding parameters for lay workers (WHO, 2013b), as well as delineations for the multi-tiered concept of health literacy (Chinn, 2011; Nutbeam, 2000). As there are various implications and applications of each term, the specific intersection of the two provides clarity to a concrete manifestation of the unified concept of lay worker health literacy. The operational definition is the level at which a worker, with no professional certification, license, or degree in the health field, is able to accurately apply basic health information and interventions in order to promote health at individual and community levels.

Defining attributes. A key component of concept analysis is the indication of defining attributes. These attributes are recurrent characteristics that exemplify elements at the core of the concept (Walker & Avant, 2011). Two defining attribute clusters were consistent throughout the literature: comprehension of health concepts, and health promotion capability. For lay worker health literacy to be established, there must be an understanding of health concepts to a degree that they can be applied to promote health (HHS, 2016).

Comprehension of health concepts. As an internal manifestation of lay worker health literacy, one must demonstrate accurate comprehension of health concepts and interventions. These concepts and interventions focus on, but are not limited to, lifestyle impacts on health, such as exercise and diet, as well as basic prevention and management of health risks (Dennis et al., 2012). Comprehension can be obtained by having lay workers in training discuss, paraphrase, and distinguish between health concepts and interventions, as applied through various formats. Text based materials, including standard literacy or ETR options, are one possible method (Sanchez & Sprager, 2013). Methods such as use of drawings or charts (Ritchie et al., 2016), picture based teaching (HHS, 2016), and/or interactive formats such as role-playing (Koskan, Friedman, Brandt, Walsemann, & Messias, 2013) may also be appropriate. Demonstration of health concepts and interventions can be done through application of these concepts in simulated practice settings, such as role-playing with fellow lay workers in the training. In addition to demonstration, measurements of comprehension can be conducted using various health literacy level determination tools (Nielsen-Bohlman, Panzer, & Kindig, 2004; Pfizer, 2016), as indicated within the empirical referents section of this paper.

Health promotion capability. An external manifestation of lay worker health literacy is rooted in the interactive ability to communicate and apply health knowledge in a way that is participatory to health promotion for individuals as well as the community (Chinn, 2011; Harris et al., 2015). In order to engage in health promotion, lay workers must develop the skills, knowledge, and efficacy to improve health by influencing behavioral intentions and attitudes towards healthy lifestyle choices (Dennis et al., 2012; Sanchez & Sprager, 2013). This capability may be reflected in measurable individual and community health outcomes, further detailed within the empirical referents section of this paper.

Case examples. Case examples provide context for application of the concept of lay worker health literacy. A model case serves as an authentic exemplar of the concept, including all defining attributes. Additional cases help illuminate mismatches for the concept. For example, borderline cases are similar but are missing a critical attribute of the concept and related cases have overlap in ideas but are missing the attributes. Finally, contrary cases indicate an example that does not represent the concept, and illegitimate cases improperly use the concept (Walker & Avant, 2011).

Model case. Maria and Gabriella, who have been working as seamstresses, travel from their remote villages each month to the town of Antigua, Guatemala in order to join a cadre of women to receive lay health worker training from a local nurse. They know that by obtaining and improving lay worker health literacy they will be able to help their communities get healthier. With each passing week, both women begin to understand the concepts better and better. This time they are both excited to return to their villages tomorrow to share what they have learned about dehydrating fruits, meats, and vegetables to help decrease malnutrition in the dry season. That will certainly help their whole communities in the months to come.

Models cases are instances in which all of the defining attributes of the concept are present (Walker & Avant, 2011). This case addresses both comprehension of health concepts and health promotion capability. Therefore, the criterion is met as a model case for lay worker health literacy.

Contrary case. Maria and Gabriella live in remote villages outside of Antigua, Guatemala. They hear through a friend that a nurse in the town will be providing lay worker health literacy training each month, and that participation in the program is incentivized with rations of food and small gifts. As the dry season is beginning to set in, and the crops quickly

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becoming exhausted, they decide that the free food would be incredibly helpful. So, the women take the bus each month to the training, and sit in the back chatting back and forth about what all has happened in each lady's village since the last meeting. The two really enjoy catching up, and figure that listening to a nurse talk about lay worker health literacy is a small price to pay for being able to get a little extra food for their families.

Contrary cases are instances in which the example does not include the defining attributes for the concept (Walker & Avant, 2011). This case involves the same individuals and trainings, but neither defining attribute of lay worker health literacy are met. Although the women are physically present in the trainings, neither are increasing their comprehension of health concepts, nor are they demonstrating health promotion capability at a community level. Therefore, the criterion is met as a contrary case for lay worker health literacy.

Related case. Maria and Gabriella live in remote villages outside of Antigua, Guatemala. They have heard through a friend that a nurse in the town will be providing lay worker health literacy training each month. Both women are interested in health but think that community development construction should take a higher priority, so enroll in non-professional level training geared towards community infrastructure development. After all, what good does learning to boil water do if there are large holes in their roofs? The women are quite certain that by fixing roofs, repairing roads, digging irrigation ditches, and providing materials to build communal laundry stations their lives will become much better. They have heard that eventually improved infrastructure can have an indirect positive impact on health for communities.

Related cases are instances in which the concept has some relation to the concept of focus, but does not contain every defining attribute (Walker & Avant, 2011). This case involves the same individuals undergoing trainings, but is indicative of a related case: lay worker

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community development. Community development construction aims to implement interventions in order to improve the quality of life for residents, which may have an indirect future impact on health. Although the concepts of lay worker health literacy are similar to the concepts of community development, neither defining attribute – comprehension of health concepts or health promotion capability – are directly addressed. Therefore, the criterion is met as a related case for lay worker health literacy.

Borderline case. Maria and Gabriella live in remote villages outside of Antigua, Guatemala. They hear through a friend that a nurse in the town will be providing lay worker health literacy training each month and are both interested in attending. Each month they meet up for the long bus ride, excited to be learning more about health. Maria's husband was injured in an automobile accident a few years ago and requires a lot of assistance with his activities of daily life, and struggling to stay healthy while permanently wheelchair bound. Gabriella, on the other hand, is the primary care giver for her elderly grandmother. Both women are looking forward to learning more health interventions to help them in their unofficial roles as home health providers for their loved ones. Unfortunately, each woman is too busy providing cares for their own loved ones that they will not be able to share any of their new knowledge with their communities.

Borderline cases are instances in which most of the defining attributes are present, but with substantial difference in at least one attribute (Walker & Avant, 2011). This case involves the same individuals and trainings, in which the women are meeting the defining attribute of attaining comprehension of health concepts. However, as the application of this knowledge is focused only on loved ones within the home, and not demonstrated as health promotion capability at a community level, they are not demonstrating both defining attributes associated with lay worker health literacy. Therefore, the criterion is met as a borderline case for lay worker

health literacy.

Illegitimate case. Maria and Gabriella live in a remote village outside of Antigua, Guatemala. They were excited when a regional theatrical company came to their village to do a production of what they thought would be play about promotoras called, "Lay Worker Health Literacy." They quickly realized, however, that the director must not understand English, and apparently had merely named the play after a billboard in downtown Antigua that showcased a beautiful woman in a white dress and hat. The play was about her struggles in love, and plotting revenge on the man who had wronged her. It was an entertaining evening; but not what was inadvertently advertised.

Illegitimate cases are instances in which the concept term is used in an entirely different, and incorrect, context (Walker & Avant, 2011). This case involves the same individuals, but contains no proper use of the concept of lay worker health literacy. Therefore, the criterion is met as a contrary case for lay worker health literacy.

Antecedents. Context is provided to the concept of lay worker health literacy through the determination of antecedents, which are incidences that must be present before the application of the concept. These antecedents lay the groundwork for successful implementation of the concept (Walker & Avant, 2011). The literature indicates four major categories of antecedents for lay worker health literacy: interpersonal engagement, interest in health, ambition, and a learning environment. It is the individual's innate connections, desires, and motivations that will drive them to seek opportunities to attain health literacy, but without a proper learning environment, there will be no opportunity for health literacy to come to fruition. Without the combined presence of all of these antecedents, lay worker health literacy may not be attained.

Interpersonal engagement. It is important that an individual being trained as a lay

worker has the ability to positively interact with those around them in socially significant ways, in order to be a change agent for health. Although homophily, or similarities between individuals engaging in the relationship, is shown to increase engagement, it is not a necessary element. The individual must be able and willing to build and maintain relationships with individuals in the community in order to establish trust (Harris et al., 2015). Communication is a key component of successful interpersonal engagement (Sanchez & Sprager, 2013).

  Interest in health. An interest in understanding and practicing health must be present for those trained as lay workers. This interest can have origins that are either intrinsic, such a personal desire to engage in health, or extrinsic, such as a community need for health intervention, or both (Chinn, 2011). Regardless of the origins, if there is no interest in health, then lay worker health literacy is less likely to occur in a sustainable manner (Sanchez & Sprager, 2013).

  Ambition. An individual being trained must be ambitious in order to engage in attaining lay worker health literacy. As training and application will later be involved, ambition and self-motivation must be strong enough to persist through the challenges accompanying new materials and roles. This ambition must also include the desire to function at a relatively autonomous level. If the motivation to do so were not present, then the likelihood of attaining lay worker health literacy would be decreased (Chinn, 2011; Harris et al., 2015; Squires & O'Brien, 2012).

  Learning environment. Access to appropriate training opportunities is imperative for lay work health literacy. This access includes the presence of an educator and appropriate learning materials as well as opportunities to ask questions and gather clarifications (Chinn, 2011). Adult and social learning theories are another important aspect of a proper learning environment, as the method used to teach is as important as the content for ensuring lesson comprehension (Harris et

al., 2015). This environment should include opportunities for both formal education, such as structured lessons, and informal education, such as storytelling or community-based sharing sessions and walk-through surveying (Ritchie et al., 2016).

Consequences. Context is further provided to the concept of lay worker health literacy through determination of consequences, which are incidences that result from implementation of the concept (Walker & Avant, 2011). Four main groupings of consequences were identified as a result of lay worker health literacy. These consequences include enhanced decision-making, improved health access, community empowerment, and the creation of praxis. Although it is possible to reach these consequences through other avenues than lay worker health literacy, fulfillment of the concept will lead to these outcomes.

Enhanced health related decision-making. Lay worker health literacy contributes to a better understanding of risks, prevention, and maintenance involved with health concerns such as disease or injury (Nutbeam, 2000). This understanding allows lay workers, based on their health literacy training, to better gather information on individuals or situations. They can then make safer, more appropriate decisions based on their assessments (Dennis et al., 2012). Enhanced decision-making can also lead to increased accuracy in determination of preventative measure and interventions.

Improved health access. At an interactive level, lay worker health literacy can provide improved access to health knowledge and resources (Hammerton & Gottlieb, 2014). Aspects of improved health access include increased awareness of available preventative and treatment-based health opportunities, and reduced health inequities for those now serviced by the lay worker (Harris et al., 2015). This access can reduce the burden of disease within communities and improve the quality of life for individuals, potentially decreasing both individual and

communal morbidity and mortality rates (Dennis et al., 2012). Often the improved health access is diagnosis or intervention specific, such as for diabetes (Henderson et al., 2013), tuberculosis (Ritchie et al., 2016), smoking cessation (Harris et al., 2015), mental health (Mehrotra et al., 2014), or a sexually transmitted infection (Lazarus et al., 2014). In other cases, the improved health access is more universal in scope (Hammerton & Gottlieb, 2014).

Community empowerment. Lay worker health literacy builds a bridge among individuals, communities, and health services to enhance communal wellbeing (Sanchez & Sprager, 2013). For example, health literacy creates compounding educational empowerment. The initial empowerment that the lay worker has gained through increasing their own health literacy is then shared with individuals in the community. This sharing allows the community as a whole to gain more control over their health outcomes (Harris et al., 2015). The interactive quality of health literacy encourages "bottom-up" participation, where the community feedback results in increased accuracy in identifying their health needs and concerns. Empowerment fosters collaboration and communal trust as well as the potential to influence societal norms that may be impeding health (Hammerton & Gottlieb, 2014; Harris et al., 2015).

Creation of praxis. The process of engaging lay workers in cycle of reflection and action, based on health literacy, allows them gradually take more and more control over both individual and communal health. This transition offers a platform for them to take the health theories obtained through health literacy training and apply them in the real world (Koskan et al., 2013; Nkonki et al., 2011; Ritchie et al., 2016).

Empirical referents. Empirical referents allow for determination of the concept's existence in the real world, as well as parameters for measuring the concept (Walker & Avant, 2011). As is customary with empirical referents, those associated with lay worker health literacy

mirror the defining attributes of this concept: comprehension of health concepts, and health promotion capability. Measurements can be obtained for each of these defining attributes.

The comprehension of health concepts can be measured using various tools. If health literacy was attained through text based training methods, then theoretically health literacy levels could be measured using language-adapted versions of the Rapid Estimate of Adult Literacy in Medicine test or the Test of Functional Health Literacy in Adults (Nielsen-Bohlman et al., 2004). Currently, most tests are only available in English, and are geared towards the clinical setting. Only the Newest Vital Signs test has a Spanish-English version (Pfizer, 2016). Tests measuring some facets of health literacy, such as clinical phrases, can also be found in Arabic, Chinese, Farsi, French, Korean, Russian, Tagalog, and Vietnamese (Duke University, 2016). However, there are more than 6,900 distinct languages in the world, as well as dialect derivities of each, and the minor languages are most commonly found in rural regions (Anderson, 2012). As these rural areas are a key demographic for the training of lay workers, testing tools may need to be further translated into the minor languages, by individuals who are fluent in both the major and minor languages.

If health literacy was established using visual information processing, then the evaluation tools should match this method. Although an exact tool for measuring visual health literacy does not exist, one could be patterned after successful tools such as one based on a visual checklist approach (Townsend, Sylva, Martin, Metz, & Wooten-Swanson, 2008) or the pictograph comprehension tools created by the Robert Wood Johnson Foundation (Kim, Nakamura, & Zeng-Treitler, 2009). Regardless of the exact tool, verification of visual literacy is important (Hammerton & Gottlieb, 2014). If role-playing was the method of instruction used, then return demonstration assessment would be appropriate for measuring comprehension.

Health promotion capability, on the other hand, could be measured by implementing the Health-Related Quality of Life tool (HRQoL), available in both English and Spanish, throughout the communities serviced by the lay worker (Center for Disease Control, 2011). Another measurement for health promotion capability could be periodic comparisons of morbidity and mortality reports for the applicable communities. With either of these approaches, health promotion capability could be established through positive trends in health outcomes, making allowance for the influence of other concurrent factors.

Summation and Contributions to Health Education

As massive shortages of health workers continue to increase amidst rapid changes in diseases and population growth, one suggested intervention is the generation of more lay workers, specifically with adequate health literacy. This analysis of lay worker health literacy included adequate defining attributes, antecedents, consequences, and empirical referents to provided clarity to the concept. Case examples were also provided to clarify the appropriate application of the defining attributes in order to reflect a model case.

Providing a more comprehensive understanding of the concept of lay worker health literacy may be beneficial to those training lay workers as well as those creating materials to enhance health literacy for this population. Also, creation of an operational definition for lay worker health literacy provides cohesion for analysis and application of the concept, as it contributes to knowledge development for global health interventions through lay worker training.

The defining attributes – comprehension of health concepts, and health promotion capability – indicate both internal and external manifestations of lay worker health literacy. Application of these attributes will contribute to creating cadres of competent, functional lay

workers that can engage in providing better health outcomes for individuals and communities in

the world's most underserved and impoverished regions.

Chapter 3: Manuscript 2

Development and usability testing of pictorial action instructions: A feasibility study

The second manuscript focuses on developing, refining, and testing the usability of literacy-adapted training materials to construct a humanitarian engineering project. Specifically, pictorial action instructions (PAI) were developed, using best practice guidelines and expert review, to illustrate how to construct a solar bottle bulb. Then, a feasibility study was conducted with five low-literacy adults to refine the PAI by improving clarity and comprehensibility, as well as test to the PAI's usability. This study resulted in a usable set of PAI for constructing a solar bottle bulb, to be used as an intervention for further usability testing on a larger scale. The second manuscript also provides recommended steps that can be taken to develop, refine, and test PAI for other humanitarian engineering projects in the future.

Written permission was obtained from the coauthor to include this manuscript in the dissertation (Appendix B). Furthermore, this manuscript is currently under-review with the *Information Design Journal* (John Benjamins, 2018; Appendix C), a peer-reviewed international journal with a focus on information design.

Cadman, K. P. & Feng, D. (2018). *Development and usability testing of pictorial action instructions: A feasibility study*. Manuscript in preparation, School of Nursing, University of Nevada, Las Vegas.

Abstract

The aim of this study was to develop, refine, and assess the usability of pictorial action instructions in training low-literacy individuals to build a basic humanitarian engineering project. Health in low- and middle-income countries is disproportionately affected by environmental hazards, often mitigated by such projects, but widespread literacy deficits often necessitate literacy-adapted materials for training. Evidence supports using pictorial action instructions, so project-specific instructions were developed, refined, and tested, with the intent of later testing them abroad. Development was based on best practice guidelines for illustrations and easy-to-understand text. Instructions were then reviewed by literacy specialists for content and formatting. Next, a feasibility study was conducted in Utah with five low-literacy adults who were trained to use the instructions and provided with the tools and materials to individually construct the project. Usability metrics gathered included construction efficiency and effectiveness, user satisfaction, and self-efficacy. Construction effectiveness was 100% and user satisfaction and self-efficacy were both high. Participants provided feedback to improve illustrations' clarity by changing item proximity and combining or separating steps, and revisions were made. In future instructional development, it would be beneficial to include low-literacy individuals when making the initial sketches to enhance sequence clarity before finalizing the illustrations.

Introduction

Health in low- and middle-income countries (LMIC) is disproportionally affected by environmental hazards, which often lead to adverse health outcomes and increased mortality rates (Health and Environmental Linkages Initiative [HELI], 2016). Projects have been designed to reduce these hazards, but widespread literacy deficits in the most underserved communities often present a barrier for training individuals in project construction. Therefore, literacy-adapted training instructions are necessary to grant broader access to information for those with the most need for these interventions. One way to increase understanding for low-literacy individuals is by providing sequential, picture-based instructions, known as pictorial action instructions (PAI). In order to ensure that the instructions are usable, they must be designed based on best practice guidelines and piloted locally before being used for further testing abroad, in Guatemala.

Objective

The aim of this feasibility study was to develop, refine, and assess the usability of PAI to train low-literacy individuals in building a basic humanitarian engineering project. The project selected was the solar bottle bulb, which is a simple structure that uses refraction of the sun's rays to light indoor spaces during the day. Usability of the instructions was assessed by measuring effectiveness and efficiency of project construction, participants' levels of user satisfaction, and self-efficacy (International Organization for Standardization, 1988). The instructions underwent multiple revisions to improve clarity and participant comprehension, in order to develop PAI that can be used in a randomized control trial that will be conducted in Guatemala.

Background

Environmental hazards, such as unsafe water, poor sanitation, indoor smoke inhalation,

and unintentional acute poisoning disproportionately have an adverse effect on health in low- and middle-income countries (LMIC). These hazards can lead to severe health conditions such as diarrhea or respiratory issues, which are responsible for millions of deaths annually (HELI, 2016). Humanitarian engineering projects have been designed to mitigate these hazards, and databases of these projects are present online through groups such as Engineering for Change (2016). Despite this, the majority of the instructions are text-based, and overall literacy rates in LMICs only range from 57-74%, with rates decreasing sharply in rural regions (World Bank 2016a), where the projects are most needed. Video options are also available for some projects, but are not accessible in many underserved regions as nearly 33% of the world lacks mobile broadband or Wi-Fi, and the majority of the 4.8 billion people without reliable internet live in LMICs (Dobush, 2015). Therefore, instructions must be adapted to increase usability for those with the greatest need for these projects.

An evidence-based method for addressing literacy barriers in training is the use of pictorial action instructions (Browder, Wood, Thompson & Ribuffo, 2014; CDC 2010; Haaland, Akogun & Oladepo, 2001; Philips & Vollmer, 2012; Shah, Khan, Maqsood & Khan, 2015; Watkins 2014). Rather than text-based literacy, PAI are a series of sequential pictures used to convey information and communicate ideas (Eilam, 2012). The CDC (2009) and the Robert Wood Johnson Foundation (Cowgill & Bolek, 2003) recommend the use of PAI for conveying information to low-literacy individuals. Although no large-scale studies have been identified to test PAI use in assembly instructions, results from small-scale studies (Clements & Norton, 2004; Phillips & Vollmer, 2012) support a high likelihood of the method's success in larger applications.

Jakob Nielsen's (1994) concept of usability will provide the conceptual framework by

which success will be determined. This concept is defined by the International Organization for Standardization (IOS, 1998) as an assessment of effectiveness, efficiency, and user satisfaction related to achieving a specific goal in a specific environment. Self-efficacy will also be assessed, as it has been found to have a strong correlation with usability (Martin, 2007).

Methodology in Preparation for Feasibility Study

   Preparation. The PAI were developed based on best practice guidelines for illustrating people and objects, as well as the inclusion of text in easy-to-read materials. A panel of literacy specialists reviewed the instructions to ensure that all criteria for content and formatting were met, and revisions were made accordingly. A feasibility test was then conducted, using the revised instructions, to measure usability and further improve clarity within the illustrations.

   Humanitarian engineering project selection. Project selection was based on an assessment of environmental hazards in a community in rural Guatemala. Community selection was based on literacy deficits, with more than 40% of adults in the area never completing primary school (UNESCO, 2012), making it an ideal location to test PAI. Furthermore, the selected community is among the 25% of Guatemala's rural population without electricity (World Bank, 2014).

   Based on identification of this environmental hazard, the solar bottle bulb (Liters of Light, 2016) was selected for construction in the basic humanitarian engineering project as it can provide a safe and affordable light source for those without electricity. More than 80% of the 1.2 billion people in LMICs without electricity use kerosene lamps or candles indoors (Furukawa, 2012; World Energy Outlook, 2016). The indoor use of candles or kerosene lamps increases risk for indoor smoke inhalation and burns from kerosene lamps and candles used indoors (Lam, Smith, Gauthier & Bates, 2012; Pokhrel et al., 2010). The solar bottle bulb costs less than one

U.S. dollar to make, and mimics a 55-watt bulb (Kuo, 2017), potentially lighting a 40 square meter space (Liter of Light, 2012).

After attaining legal permission from Liter of Light (Appendix D), previously produced instructions for the solar bottle bulb (Liter of Light, n.d.) were converted into PAI using best practice guidelines for illustrating, sequencing, and easy-to-read wording.

Instruction best practice guidelines. As the PAI included objects, sequences, people, and words, guidelines for each were followed in designing an initial draft of the instructions.

The most frequently used guidelines for the inclusion of objects and sequences in PAI come from the work of Schumacher (2007). He identified three aspects of illustration that optimize comprehension. First, illustrations with simple black and white line drawing, and no shading, are most clearly interpreted. Only necessary items should be included in these line drawings, eliminating decorative or distracting items. Second, to increase comprehension of the transitions between sequential steps, the vantage point must remain consistent, unless intentionally indicating a need to shift perspectives. Finally, comprehension of individual steps and transitions is best when the size of the objects do not change from frame to frame, and the only object that varies is the object of focus.

Best practice guidelines for the inclusion of people in PAI are based on multiple studies conducted by Haaland, Akogun, and Oladepo (2001) in various LMICs. Their findings include the importance of developing the simplest form that is personally relatable to those who will use the instruction, including features such as hairstyle, jewelry and local dress, or architecture that is similar to that seen in the community. However, too many details in features or architecture are seen as distracting and exclusive of those who have slightly different features or architecture, particularly in societies where these details are used to distinguish between communities or

tribes.

Guidelines for wording in the instructions originate from the CDC's (2009) *Simply Put: A Guide for Creating Easy-to-understand Materials*. This document provides considerations for the incorporation of text in materials for low-literacy individuals, including font sizes and styles, as well as layout. Recommendations include the use of serif font with emphasized words in bold and avoiding the use of fancy lettering, all caps, italics, or underlining. Furthermore, the CDC recommends conveying action through pictographs with necessary indicator words, instead of text, when possible. Finally, testing of the readability level must be completed to ensure the wording is at an appropriate literacy level for those who will be using the materials (CDC, 2009). As the instructions are intended for Spanish speakers, the Spanish Lexile Analyzer (Lexile, 2016) was selected to test readability.

Literacy specialists review. The initial draft of the Spanish-language instructions was evaluated by a native Spanish-speaking literacy education specialist, using the CDC (2009) Checklist for Easy-to-understand Print Materials (Appendix E) to ensure the draft met all applicable criteria for both content and formatting. The specialist concluded that all criteria were met, but recommended consulting three other, non-Spanish-speaking literacy specialists to further review the formatting criteria. Feedback from the specialists indicated that the materials met "easy-to-understand" criteria for content and format, but two specialists stated that words were not necessary in the sequential instructions, as the illustrations were clear enough to convey the message. When this feedback was shared, all four specialists agreed that the text was redundant; thus, the text was removed from the sequential illustrations. Words remained on the page to indicate the project's necessary materials and tools to ensure comprehension of the items seen in the illustrations.

Feasibility Study

      The revised PAI were tested in a single-day feasibility study at a community center in Utah in March 2017. The study focused on assessing the usability and improving the clarity of the PAI before use in a randomized control trial in a LMIC.

      Sample. As per guidelines set forth for piloting usability testing (Nielsen, 2012), recruitment was done to select five participants. Recruitment was done via an announcement made by a city councilmember as he conducted a community meeting over Hispanic affairs. He informed the attendees that five people, meeting the inclusion criteria below, were needed to participate in a one-day study to learn to build a basic project, and that no construction background was necessary. Interested adults were instructed to contact a Spanish interpreter hired by the investigator. The first five individuals to call, who also met the criteria, were selected.

      All participants met the following inclusion criteria: 18-64 years-old, native Spanish speakers, no physical impairments that would preclude the use of basic hand tools (CDC, 2015), less than a seventh-grade education, and able to correctly identify at least 8 of 10 pictures of basic hand tools used in rural building (van Winden, 1990) by name and function (Appendix F). This sample was as similar as possible to those who will participate in a future randomized control trial in Guatemala.

      Methods. A demonstration was given by the investigator, in conjunction with a Spanish-English interpreter, to show participants step-by-step how to construct the solar bottle bulb using the PAI. Following the demonstration, the investigator, interpreter, and participants took a one-hour break. The break was included to ensure that participants were not relying on immediate memory recall (Grinnell, 2017) for construction, but were instead relying on the instructions for

guidance.

Following the break, participants were provided the tools and materials necessary for the

project, as well as the PAI, and were asked to construct the project individually. Initial plans to

video-record the construction were altered, as all of the participants were undocumented

immigrants and stated that, with the current sociopolitical climate, they feared being recorded

could increase their risk of deportation. Monitoring of efficiency and effectiveness, in the

absence of video-recording, was done by the investigator and an interpreter trained to observe

project construction.

Usability metrics and results. Usability testing of the PAI was done by assessing the

three components associated with the concept of usability (Nielsen, 1994): effectiveness,

efficiency, and user satisfaction. The secondary concept of self-efficacy was also measured, as

evidence indicates that usability problems can decrease self-efficacy, and successful step

completion maintains or increases self-efficacy levels (Martin, 2007).

Effectiveness. Effectiveness was determined by calculating the completion rate (# task

steps successfully completed / # total task steps X 100%) of the twelve steps involved in this

task. All five participants were able to achieve 100% effectiveness by completing all twelve

steps correctly.

Efficiency. Efficiency was calculated by recording the task time (start time subtracted

from end time) rounded to the nearest whole minute. Construction times ranged from 25-40

minutes.

User satisfaction. User satisfaction was calculated using a one-time administration of the

validated three-item After-Scenario Questionnaire (ASQ; Lewis, 1995; Appendix G) to assess

overall satisfaction with completing the project. Administration and response recording were

completed verbally by the interpreter, who was trained by the investigator to use this tool. All five participants rated each of the three items a 5 (on a scale from 1 [strongly disagree] to 5 [strongly agree]). Acceptable psychometric reliability and sensitivity ($F_{(7,126)}$=8.92, $p < .001$), and concurrent validity (0/1 coding for failure/success = -.40 ($n = 48$, $p < .01$)) were established.

 Self-efficacy. Self-efficacy was measured using an adaptation of the validated Online Learning Value and Self-Efficacy Scale (Artino & McCoach, 2008; Appendix G), administered upon construction completion. Ten of the eleven items in the original scale were applicable, and were thus retained and adapted. The word "project" replaced references to an "online course" in the first five items and "method of instruction" in the remaining five items. In prior studies, the subscales task value ($\alpha = .85$) and self-efficacy ($\alpha = .87$) correlate with each other (.289, $p<.01$). Administration and response recording were done verbally by the interpreter, who was trained by the investigator to use this tool. Each item's rating averaged between 4.8 and 5 (on a scale from 1 [strongly disagree] to 5 [strongly agree]).

 Instruction clarity. Upon completion of the project, the interpreter asked the participants five questions about clarity of the instructions (Appendix H). Although all five participants stated that, overall, the instructions were clear to follow; two recommendations were made to improve the proximity of items in illustrations for steps two and seven. For step two, participants requested clarification that the second circle should be drawn within, not around, the first circle. As depicted in Figure 1, illustrations for step seven were revised after a request was made to
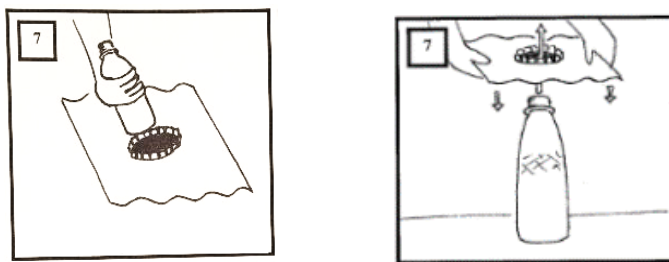

Figure 1. Step seven original and revised versions.

illustrate the bottle being placed in the sheet metal from below, not above. Furthermore, participants felt that step eight, applying rubber sealant around the bottle, was unnecessary and could easily be included with step twelve, applying rubber sealant around the lid. All other steps and transitions between steps were reported to be clear. Participants additionally stated that both the materials page and illustrations clearly conveyed all materials and tools.

Discussion

Participant statements. In addition to the formal data gathered on usability and instruction clarity, the participants provided positive feedback about their involvement in the study. One woman, unable to read or write anything more than her name and whole numbers, expressed overwhelming feelings of empowerment and gratitude as she, for the first time in her life, could independently follow a set of written instructions. All five participants asked to take their completed projects home. Although they all have electricity in their homes, participants stated that they were incredibly proud of their finished products and wanted to show them to friends and family. Moreover, three participants asked permission to take pictures of the instructions on their phones and planned to send the pictures to family members in rural areas of Mexico. All of the participants felt confident that, with a copy of the PAI, they could reconstruct the project in the future, even years later, and could teach others to successfully construct the project, as well.

Limitations. The inability to video-record participants meant that all construction effectiveness observations had to be done in real time. Accuracy in observation could have been increased by the ability to watch the construction video multiple times, focusing on a different participant each time. Furthermore, although the inclusion criteria were the same for the participants in Utah as those for the future study in Guatemala, those in the feasibility study all

lived in a suburban area, whereas the study in Guatemala will be conducted in a rural

community. Finally, as no required gender distribution was indicated in the study design, the first

five individuals to contact the interpreter were all women, resulting in no gender variation within

the study.

        Implications. The process of development, revision, and testing used in this study

produced PAI that are anticipated to be useful in training low-literacy individuals in LMICs. One

recommendation for future application would be to include low-literacy individuals earlier in the

process, when doing preliminary sketches, to determine the clarity and comprehensibility of

items, steps, and sequences before finalizing the illustrations. Considering this, the following

steps are recommended for future projects:

    1. Conduct an environmental hazards assessment in the community

    2. Select a humanitarian engineering project that addresses the hazard (taking into

       account availability of tools and materials) to use as an intervention

    3. Use best practice guidelines to sketch initial drafts of PAI

       a. Have low-literacy individuals assess step sequencing and item proximity for clarity

       b. Use a text analysis tool to determine literacy level of words in PAI

    4. Finalize PAI using feedback from low-literacy individuals and text analysis tools

    5. Test the usability of the PAI for the specific humanitarian engineering project

Conclusion

        Evidence provided through the feasibility study indicates a strong potential for PAI to be

used in training low-literacy individuals to construct basic humanitarian engineering projects.

Construction effectiveness was 100%, and user satisfaction and self-efficacy were both high.

Additionally, feedback from the participants led to revisions that are anticipated to improve the

PAI's clarity and comprehensibility. Thus, the final version of the instructions (Appendix I) should be ready for use in a randomized control trial in which usability will be compared between training with PAI and demonstration-only training, the most common method of instruction implemented for these projects (Guttentag, 2009).

The process of developing, refining, and testing the PAI for the solar bottle bulb resulted in recommended guidelines that can be used to create PAI for other humanitarian engineering projects in the future. If usability of these instructions can be established for training low-literacy individuals in LMICs to construct their own projects, then this approach can potentially be empowering, enhancing the sustainability and scalability of such projects in the world's most underserved regions.

Chapter 4: Manuscript 3

Using pictorial action instructions to build a basic humanitarian engineering project:

A randomized control trial

The final manuscript is a randomized control trial (RCT) that was conducted with low-literacy adults in rural Guatemala. The PAI that were developed, revised, and tested in the feasibility study served as the intervention in a RCT that compared usability of PAI-based training to usability of demonstration-only-based training in construction of a solar bottle bulb. Measurements for effectiveness, efficiency, user satisfaction, and self-efficacy were compared between the intervention and the control group. This study provided a data-driven assessment of the PAI as a training method, showing significant increases in construction accuracy and self-efficacy. Findings from this study raise opportunities for future research, both to test this PAI among low-literacy individuals in different contexts, as well as to develop and test PAI for other humanitarian engineering projects.

Written permission was obtained from the coauthor to include this manuscript in the dissertation (Appendix B). Furthermore, this manuscript is currently under-review with the *Journal of Humanitarian Engineering* (Engineers Without Borders, 2018; Appendix C), a peer-reviewed international journal with a focus on humanitarian engineering education and its application in practice.

Cadman, K. P. & Feng, D. (2018). *Using pictorial action instructions to build a basic humanitarian engineering project: A randomized control trial.* Manuscript in preparation, School of Nursing, University of Nevada, Las Vegas.

Abstract

Humanitarian engineering projects have been designed to mitigate environmental hazards that disproportionately affect health in low- and middle-income countries. However, widespread literacy deficits can create barriers in training low-literacy adults to construct these projects, indicating a need for literacy-adapted training materials. A randomized control trial in rural Guatemala tested the usability of pictorial action instructions, compared to demonstration-only methods, in training low-literacy adults (N = 60; n = 30 per group) to construct a solar bottle bulb. Fourteen days after the training, participants individually constructed the solar bottle bulb. The intervention group received pictorial action instructions to guide them, and the control group completed construction based on memory. Usability was evaluated by measuring the effectiveness and efficiency of construction, as well as user satisfaction and self-efficacy levels. Effectiveness and self-efficacy were significantly better among those in the intervention group compared to the control group. Considering this, the findings support the use of pictorial action instructions in training low-literacy adults to construct humanitarian engineering projects. This method may allow more individuals in rural regions of low- and middle-income countries to successfully construct their own humanitarian engineering projects in a way that is sustainable and scalable. Further research is needed to test these instructions in different settings, on a larger scale, as well as to test the long-term effects of using pictorial action instructions.

Introduction

Environmental hazards are responsible for 25-35% of global deaths and the global burden of disease each year, and disproportionately affect health in low- and middle-income countries (LMICs). The two most prominent hazards, unsafe water and poor sanitation, and indoor smoke inhalation, markedly increase morbidity and mortality in the world's most underserved regions, and are responsible for millions of deaths each year (Health and Environmental Linkages Initiative [HELI], 2016; World Health Organization, 2016). While some hazards are difficult to control at the household level, such as urban air pollution or contaminated shared water sources, indoor smoke inhalation is easier to manage (HELI, 2016). Smoke inhalation is frequently associated with indoor stoves and kerosene lamps, which are used by an estimated 2.8 billion people worldwide (Muindi et al., 2016). The indoor usage of stoves and kerosene lamps can cause respiratory infections (Lam, 2014; Mills, 2016; Pokhrel et al., 2010), explosions and burns (Maritz, Wallis, Van Der Merwe & Nel, 2012), and elevated neonatal death rates (Epstein et al., 2013).

Humanitarian engineering projects can mitigate some of these basic environmental hazards, but widespread literacy and technological deficits often found in LMICs can present barriers for implementing these interventions. Currently, instructions for many of these projects are text-based or video-based. Text based instructions limit use among low-literacy individuals. Video-based instructions do not require participants to be literate; however, 4.8 billion people globally (predominately located in LMICs) live without reliable internet access (Dobush, 2015). Therefore, even when individuals know of a project, the knowledge is not always usable among those needing these interventions. Adapting training methods to expand access to low-literacy individuals without the internet could help transition knowledge to action, which promotes the

sustainability and scalability of such projects in underserved regions (Clark, van Kerkhoff, Lebel, & Gallopin, 2016).

One approach to convey instructions to low-literacy individuals is through sequential pictures, known as pictorial action instructions (PAI). This method has been shown to increase comprehension of materials in low-literacy populations. Currently, existing applications of PAI have primarily focused on medication administration (Kripalani et al., 2007), toy assembly (Phillips & Vollmer, 2012), and safety procedures (Cowgill & Bolek, 2003). To date, there have been no formal applications of PAI to grant low-literacy individuals access to usable humanitarian engineering instructions.

In this study, we assessed the use of PAI in training low-literacy adults to construct a humanitarian engineering project based Jakob Nielsen's (1994) concept of usability. This primary concept assesses the effectiveness, efficiency, and user satisfaction associated with completing a specific task (Holden & Rada, 2011). The secondary concept of self-efficacy was also assessed, as it positively correlates with usability (Bandura, 1977; Martin, 2007). Based on these concepts, it was hypothesized that the intervention group, compared to the control group, would: (a) have shorter project completion times, (b) better construction accuracy, (c) have higher levels user satisfaction and, (d) have higher levels of self-efficacy.

Methodology

Setting and project selection. A randomized control trial was conducted in Guatemala, which is 116th in the world on the Human Development Index, and has substantial literacy deficits, particularly in rural regions (GHRC, 2010; USAID, 2016). The rural community selected is in a 44,000-person municipality in the western highlands, where nearly 40% of adults have not completed primary school (UNESCO, 2012). Furthermore, the selected community is

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among the 25% of homes in rural Guatemala without electricity (World Bank, 2014), leading

many to use kerosene lamps and candles indoors (USEIA, 2017), often in homes without

windows for ventilation (Lam, Smith, Gauthier & Bates, 2012). Considering the community's

remote location and lack of technological resources, an intervention was needed that could be

constructed using easy-to-find and affordable tools and materials. Therefore, the project selected

was the solar bottle bulb. The solar bottle bulb is a structure made from metal lamina, a plastic

bottle, water, bleach, and sealant; the completed structure refracts light from the sun, mimicking

a 55-watt bulb (Kuo, 2017).

Best practice guidelines for PAI illustrations and simplified text were applied to existing

instructions (Liter of Light, n.d.), to develop PAI for constructing a solar bottle bulb. The PAI

were tested for comprehensibility and clarity during a single-day feasibility study in Utah, and

participant feedback guided revisions for the final PAI used in this study (Cadman, 2018;

Appendix I).

Sampling and recruitment. Participant recruitment was done via an announcement

made by the local health worker at a community meeting. Attendees were invited to participate

in a study to learn how to construct a solar bottle bulb if they met the following inclusion criteria:

18-64 years-old, native Spanish speakers, no physical impairments precluding the use of basic

hand tools (CDC, 2015), less than a 7th grade education, and able to correctly identify at least

80% of preselected basic hand tools commonly used in rural building (van Winden, 1990).

Power analyses were conducted for a student's t-test and multiple regression for each hypothesis,

with an alpha of .05 and power of .85, using effect sizes from prior studies on similar outcome

variables (Clements & Norton, 2004; Dowse, Barford & Browne, 2014). The results indicated a

desired sample size of 54 participants. To account for possible attrition, 60 participants were recruited, who were then randomly divided into two 30-person groups.

Study design. In a randomized control trial, usability was compared between two methods of training low-literacy adults to construct a solar bottle bulb. The intervention group received PAI-based training, and the control group received demonstration-only training, a common method used when service-based groups visit LMICs to construct projects (Guttentag, 2009). The PAI included 18 steps for project construction and installation as well as a tools and materials page.

Both trainings were conducted in the community center, by the investigator, with a Spanish language interpreter. The intervention group received construction training 24 hours after the control group. Training included a description of how the bulb functions, the tools and materials used, and a construction demonstration. Following the demonstration, each participant completed a text-based literacy assessment and a visual literacy assessment. The intervention group was provided with PAI to follow during the demonstration, and all PAI were collected afterwards to decrease intervention contamination.

Participants returned to the community center 14 days after each training to individually construct a solar bottle bulb. Participants were provided with the tools and materials necessary for the project's construction, and were assigned pre-designated work areas surrounding the community center. The intervention group was given PAI to use, and the control group completed construction based on memory. Participants were instructed to raise their hand upon completion of their solar bulbs, and their construction times were recorded. Upon completion of construction, each participant brought his or her finished product to the investigator for

inspection. Finally, participants took their assessment form to the interpreter and provided feedback regarding user satisfaction and self-efficacy.

Usability Metrics

Effectiveness. Effectiveness was calculated by dividing the number of steps successfully completed by the total number of task steps (12), then multiplying this number by 100. As the exact sequence of steps can vary somewhat and still result in successful construction, effectiveness was determined through inspection of the final product. Results could range 0-100%. The full instructions have 18 steps, but the last six were excluded as they focus on bulb installation, not construction. However, installation instructions were explained after the study to increase project sustainability and scalability.

Efficiency. Efficiency was calculated as the time lapse between task initiation and completion. All participants in each group had the same initiation time: when they were instructed to collect tools and materials to take to their work areas. Task completion times were recorded, to the nearest whole minute, when each participant finished the 12th step of construction.

User satisfaction. Satisfaction was calculated using a one-time administration of the validated three-item After-Scenario Questionnaire (ASQ; Lewis, 1995), commonly selected in usability testing. The ASQ assessed overall satisfaction with the project based on ease of construction, perception of construction times, and the support information received. Each item was rated between 1 (strongly disagree) and 5 (strongly agree). The ASQ was administered verbally, with responses recorded by an interpreter who was trained to use this tool.

Self-efficacy. Self-efficacy was evaluated once, upon construction completion, using a ten-item adaptation of the Online Learning Value and Self-Efficacy Scale, designed to evaluate

both learning value and self-efficacy (Artino & McCoach, 2008). Ten of the initial eleven items were applicable, and were thus adapted so that "online course" was replaced with "project" in the first five items, evaluating learning value, and "method of instruction" in last five items, evaluating self-efficacy. Each item was rated between 1 (strongly disagree) and 5 (strongly agree). The scale was administered verbally, and responses were recorded by an interpreter who was trained to use this tool.

Literacy measures. Text-based literacy and visual literacy were assessed as either, or both, could have a confounding influence on outcomes. Text-based literacy was measured using an adapted Native Language Literacy Screening Tool-Spanish (FLDOE, 2014), widely used to determine literacy levels in an individual's primary language. Visual literacy was assessed with the Santa Barbara Solids Test-3rd Edition (Cohen & Hegarty, 2012) to measure spatial reasoning.

Evaluation

Data analysis. Data analysis was done with R, version 3.4.2. Each hypothesis was analyzed using a student's t-test, as well as a Wilcoxon rank-sum test, based on abnormal distribution within each outcome variable. Furthermore, each hypothesis was analyzed via multiple linear regression, adjusting for the two covariates.

Results. Significance of the student's *t*-test and that of the Wilcoxon rank-sum tests was consistent for each outcome variable. Furthermore, multiple linear regressions adjusting for text-based literacy levels and visual literacy levels did not change the conclusions, and were not associated with any of the outcome variables (Table 1).

Table 1

Means, Standard Deviations, and p-Values of Usability Metrics

	M (SD)		*p*-Values		
	Control (*n* = 30)	Intervention (*n* = 30)	Student's *t*	Linear Regression	Wilcoxon rank-sum
Minutes to Construct	33.0 (8.3)	30.8 (12.4)	.420	.530	.310
Effectiveness (%)	80.0 (17.5)	95.6 (6.5)	<.001	<.001	<.001
User Satisfaction (1-5)	4.5 (0.3)	4.4 (0.5)	.470	.440	.460
Self-Efficacy (1-5)	4.2 (0.3)	4.6 (0.4)	<.001	.002	.003

It was hypothesized that the group using PAI would take less time to complete the project, would have better construction accuracy, and would report higher levels of both user satisfaction and self-efficacy than the group that received demonstration-only training.

Effectiveness was significantly better in the intervention group (95.6% versus 80%, $p <$ .001), indicating a higher rate of accuracy in solar bottle bulb construction for those using PAI compared to those constructing the project based on memory. In addition, self-efficacy levels were significantly higher for those using PAI (4.6 versus 4.2, $p = .003$) than those without.

There was no statistically significant difference between the two groups for efficiency (intervention group = 30.8 minutes, control group = 33.0 minutes, $p = .31$), or user satisfaction (intervention group = 4.4, control group = 4.5, $p = .46$).

Discussion

The results indicate that using PAI leads to significantly better outcomes for effectiveness and self-efficacy, both of which are also significant in practical application.

Construction effectiveness is the most crucial aspect of usability in practical application, as final product accuracy can influence the functionality and sustainability of the project to different degrees. While some inaccuracies may still result in an initially functional solar bottle

bulb that could deteriorate over time, errors in other steps could have an immediate effect on the safety of the product, leading to increased hazard in the home. In areas where resources are scarce, it is important that projects be well-constructed to promote project sustainability, improving the health of underserved populations in LMICs.

Those who used PAI also reported feeling more capable and confident, even if faced with technical glitches, distractions, difficult tasks, or presented with new projects. Confidence with constructing, and potentially replicating, the project can potentially lead to increased sustainability and scalability of solar bottle bulbs in the future.

Project completion time was only slightly better when using PAI. One possible explanation for this outcome is that both groups were instructed to focus on construction quality, not speed. In addition, the lack of variation in times is partially attributed to the short overall duration of construction as, even with the inclusion of outliers, there was only a 38-minute difference from the slowest to fastest completion time. In larger projects, the completion time may vary more drastically between the two different methods.

User satisfaction results did not differ when using PAI, but a ceiling effect was noted. Each item within the ASQ received a mean score exceeding four out of five in each group. The health worker explained that in this community, where resources and opportunity are scarce, stating dissatisfaction would have been perceived by participants as ingratitude, leading to apprehension that the community would then be disqualified from future projects and opportunities. Therefore, based on cultural perceptions, the results may not reflect participants' true feelings.

Limitations. Due to time constraints, the period between training and participant construction was limited to fourteen days. A longer period between demonstration and

participant construction could provide a clearer indication of the long-term differences in outcome based on training method. Furthermore, constraints in time, geography, and human resources led to evaluation of only the twelve construction steps and not the six installation steps. Although this was consistent between both groups, evaluating all of the PAI steps could provide greater variation, particularly in effectiveness and efficiency. Additionally, a limitation is present within the interpretation of the self-efficacy and user-satisfaction tools. Although both were validated prior to use, and a bilingual interpreter verified that the translations were accurate, cultural context and subtle wording variation through translation could potentially change participant perceptions. Finally, demographic information for participants was not collected due to human resource constraints. As participants had limited text-based literacy, the one Spanish-language interpreter would have needed to collect most demographic information individually for each participant. The interpreter was assisting with the training during the first session, and collecting data for the self-efficacy and user satisfaction tools during the second session, so no extra time was available for the collection of the demographic information.

Implications. Providing a training method with better usability for low-literacy individuals can help remove a barrier that currently exists between many basic humanitarian engineering projects and the individuals who need to access them to mitigate environmental hazards. As the application of PAI within this study resulted in better project accuracy and self-efficacy levels, it is conceivable that this approach could also be implemented in similar trainings for other basic humanitarian engineering projects. By removing the literacy barrier, individuals who may have previously been unable to access these projects can now learn to construct them by themselves, helping promote sustainability and scalability of such projects in underserved regions.

Conclusion and Recommendations

Using PAI to train low-literacy individuals to construct a solar bottle bulb was found to result in better construction accuracy and self-efficacy than training individuals using only demonstrations. Although efficiency and user satisfaction levels were not significantly different between the two groups, as they are key components of usability, they should be reassessed in future usability studies. To further determine the usability of PAI to train low-literacy individuals to construct humanitarian engineering projects, the following future studies are recommended: similar testing of PAI for other projects; expanding usability testing to a larger scale; testing in different settings, such as within urban slums or in other regions of the world; and evaluating long-term sustainability and scalability, including tracking the replication and dissemination of the project by participants in each group.

Chapter 5: Summary and Conclusions

In this chapter, a summary is provided for the study that was conducted, including findings, strengths, and limitations. The implications of the findings to the fields of education and practice are articulated. Furthermore, suggestions for future research are included.

Summary of the Study

This dissertation was comprised of three manuscripts that focused on granting low-literacy individuals in low- and middle-income countries (LMICs) access to health promotion interventions. The first study, a concept analysis and operational definition for "lay worker health literacy," set a foundation for training non-health professionals to apply basic health promotion interventions in their homes and communities. In the analysis, the use of picture-based instructions was mentioned as an approach for increasing training comprehension.

The second and third manuscripts focused on studies, shaped by the concept of usability, in which pictorial action instructions (PAI) were developed and tested in training low-literacy individuals to construct a basic health promotion intervention. In the second manuscript, specific picture-based instructions were developed using best practice illustration guidelines, and revised through a feasibility study to assess instructional clarity and usability estimates. In the third manuscript, a randomized control trial was conducted to evaluate the usability of the PAI, compared to demonstration-only methods, in training low-literacy adults to construct a humanitarian engineering project. The institutional review board (IRB) of the University of Nevada, Las Vegas, granted permission to conduct both the feasibility study (Appendix J) and the randomized control trial (Appendix K).

Findings

In the first manuscript, a comprehensive concept analysis was done to synthesize two

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existing concepts, "lay worker" and "health literacy," into a newly articulated concept of "lay worker health literacy." In addition to the analysis, the following operational definition for this concept was created: "the level at which a worker, with no professional certification, license, or degree in the health field, is able to accurately apply basic health information and interventions in order to promote health at individual and community levels" (Cadman, 2017, p. 3). The analysis of this integrated concept, and resulting operational definition, may be beneficial to those training lay workers as well as those creating materials to enhance health literacy.

The feasibility study, explained in the second manuscript, found that applying best-practice illustration guidelines to previously-created instructions can result in PAI that are clearly understood by low-literacy adults. Furthermore, feasibility testing with the PAI resulted in minor revisions to further clarify specific parts of the illustrations, making them easier to comprehend. In addition to the formal findings, the participants in this study expressed feelings of empowerment and pride associated with independently following written instructions for the first time. All of the participants felt confident that, when using the PAI, they could reconstruct the project and teach others to construct the project, even years later.

The randomized control trial described in the third manuscript found that, when comparing PAI-based training to demonstration-based training to construct a basic humanitarian engineering project, those trained with PAI had better project effectiveness and higher levels of self-efficacy. In addition to the differences being statistically significant, these two outcomes are significant in practical application. Effectiveness was determined through construction accuracy, which is crucial to ensuring the functionality and sustainability of the project.

Overall, a method was identified for training low-literacy individuals to construct a basic health promotion intervention. This method was further developed through application to

instructions for a specific intervention: a solar bottle bulb. The resulting instructions were shown to promote better construction accuracy, and self-efficacy levels, than the current approach to training. Therefore, findings indicate that pictorial action instructions can be developed and used to train low-literacy individuals to construct their own projects.

Strengths. The formative research approach taken in the first two manuscripts provided useful information on which to base the intervention in the final study. The concept analysis uncovered the use of picture-based instructions to improve comprehension when training low-literacy individuals. Then, the development and testing of specific picture-based instructions led to improvements in clarity and comprehensability of the instructions before their use in the final study. This approach resulted in the intervention being evidence-based prior to summative testing.

Limitations. Constraints associated with geography, time, and human resources limited the scope of this study. The feasibility study tested participants who were as similar as possible to those who would participate in the randomized control trial, but cultural contexts varied between the two groups. Although all inclusion criteria were the same, those in the feasibility study lived in a suburban region of Utah, whereas participants in the randomized control trial lived in a remote community in rural Guatemala. Though neither group had formal education beyond an elementary level, they would have been exposed to different approaches, attitudes, and resources in their local environments, which could alter comprehension levels of the same materials.

Time constraints were a factor in the randomized control trial, limiting the period between training and participant construction. A longer lapse in time could better indicate the long-term differences in outcome based on training method. Furthermore, with homes spread

throughout the highland, and limited human resources, only the construction steps were evaluated and not the project installation, which could have provided greater variation, particularly in effectiveness and efficiency. Finally, a limitation was present due to language barriers. All participants were Spanish-speaking, a language in which neither investigator is fluent, so bilingual interpreters were used in the feasibility study and randomized control trials. Although the interpretations and translations were accurate, cultural context and subtle wording variations could have potentially changed participant perceptions.

Implications

Providing a training method with better usability for low-literacy individuals can reduce a barrier that exists between many basic humanitarian engineering projects and the individuals who need to access them. As findings in this dissertation indicate that using PAI can result in better project accuracy and self-efficacy levels, it is conceivable that this approach could also be implemented in similar trainings for other basic humanitarian engineering projects. By removing the literacy barrier, individuals who may have previously been unable to access these projects can now learn to construct them by themselves, helping promote the sustainability and scalability of such projects in underserved regions.

Educational implications. The concept analysis and operational definition for "lay worker health literacy" form a beneficial foundation on which to shape educational approaches, including the creation of educational materials designed specifically to train these lay workers. Furthermore, indicating the need for literacy-adapted instructions may make educators more cognizant of the needs of those they train, to best match the materials to the learner.

Practice implications. The randomized control trial demonstrated that construction accuracy and participant self-efficacy are better when PAI are used in training low-literacy adults

to construct humanitarian engineering projects. These findings may influence how the field of humanitarian engineering approaches trainings in regions with widespread literacy deficits. Additionally, there may be an increased interest in developing PAI for other humanitarian engineering projects to improve construction accuracy, as this can enhance the sustainability and scalability of the projects. Furthermore, those in the field of humanitarian engineering, or other professionals who need to train low-literacy individuals to complete tasks, can create PAI using the specific steps that have been provided based on the feasibility study. These steps can guide the development and revision of PAI to promote usability before implementation in final training.

Suggestions for Future Research

Numerous studies could be conducted to further determine the usability of PAI in training low-literacy individuals to construct humanitarian engineering projects. First, PAI for other basic humanitarian engineering projects could be developed and tested to determine the scope of the application of this approach to these projects. Second, usability testing for the PAI in this study, as well as other potential PAI, could be conducted on a larger scale, although caution must be used not to not have too excessive of a sample size in order to maintain accurate yet relevant results. Third, testing of PAI can be done in different settings. The final study in this dissertation was conducted in a rural region of Guatemala, but it would be beneficial to also test the PAI in other environments where these projects could prove positive, such as urban slums or other LMICs. Finally, a longitudinal study could be conducted to evaluate the sustainability and scalability of the intervention and observe if differences occur in the replication and dissemination of the project by participants depending on the training method received.

Appendix A

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Appendix B

**Co-author Written Permission for Manuscripts 2 and 3**

As second author, I grant permission for inclusion of the following two manuscripts in this dissertation document. *Development and usability testing of pictorial action instructions: A feasibility study* is included as Chapter3: Manuscript 2. *Using pictorial action instructions to build a basic humanitarian engineering project: A randomized control trial* is included as Chapter 4: Manuscript 3.
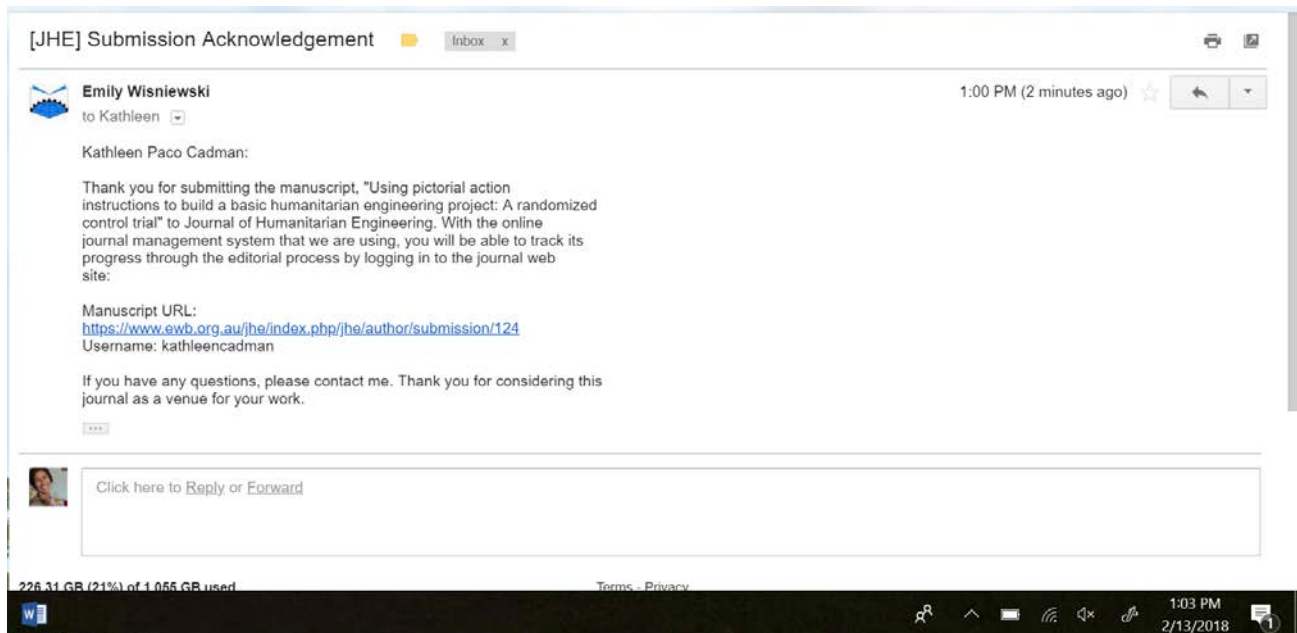

Du Feng, PhD

Appendix C

Proof of Submission for Manuscripts 2 and 3

Manuscript 2 Submission to the Information Design Journal (2/11/18)
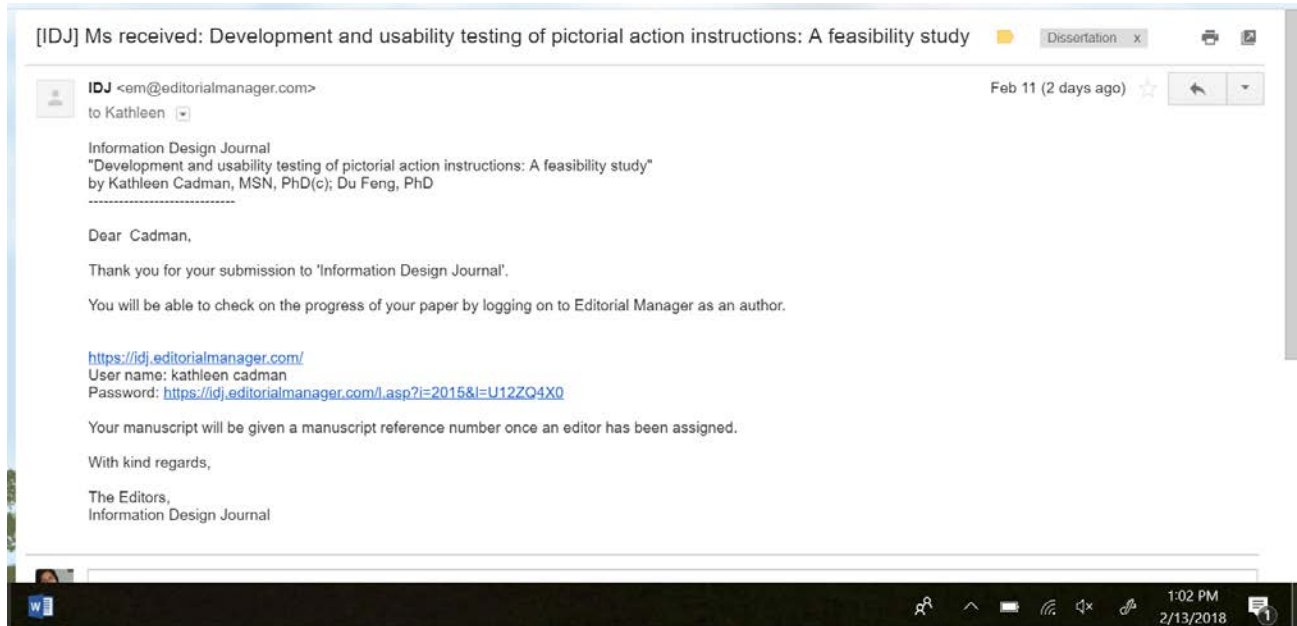
Manuscript 3 Submission to the Journal of Humanitarian Engineering (2/13/18)

Appendix D

Legal Permission from Liter of Light

MATERIAL RELEASE FORM

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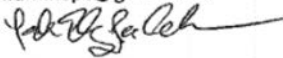
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NAME OF AUTHORIZED REPRESENTATIVE:
Title

Conforme	:
Name	: Kathleen Paco Cadman
Position	: Student- UNLV School of Nursing
Email	: i.am.kepc@gmail.com
Signature	:

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Appendix E

Easy-to-understand Materials Checklist

Adapted from CDC (2009)
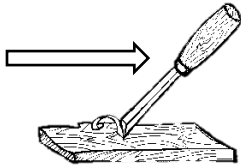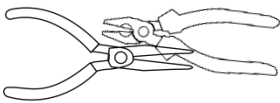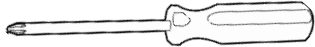
Content
- Has the information that is "nice to know" but not necessary been removed?
- Is the most important information at the beginning of the document?
- Have action steps or desired behaviors for the audience been identified?
- Is the language and content culturally appropriate?
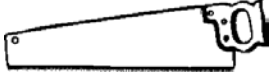- Are the visuals culturally appropriate?
- Are the instructions accurately translated into the appropriate language for the intended audience?
- Has the complexity of the language been tested for comprehension?
- Have jargon and technical language been removed?
- Are concrete nouns, an active voice, and short words/sentences used?
- Is the style conversational?

Formatting
- Does the document have a lot of white space, with at least ½ inch margins?
- Is the print large enough (using at least 12 point font)?
- Have bold, italics, and text boxes been used to highlight information?
- Do these instructions avoid using all capital letters?
- Is text justified on the left only?
- Is the cover attractive (visually appealing) to the intended audience?
- Does the cover include the purpose of the instructions, and show who the audience is?
- Are visuals simple and instructive (rather than decorative)?
- Do visuals help explain the message in the text?
- Are the visuals placed near the related text (included as captions)?
- Is the information presented in and order that is logical?
- Is the information chunked, using headings and subheadings?

Appendix F

Basic Hand Tools Identification Form

Picture	Name	Use
	chisel *cincel o* *el formon*	carve, chisel, cut wood or metal when used with hammer *cincel, corte de madera o metal cuando se utiliza con martillo*
	hammer *el martillo*	hit nails, strike surface, remove nails *uñasde golpe, huelga de superficie, quitar las uñas*
	pliers *los alicates*	tighten, bend metal, cut wire *apriete, la curvade metal, corte el alambre*
	nails *uñas*	attach surfaces, poke/punch hole *adjuntar superficies*
	tape measure *la cinta metrica*	measure dimensions or distance between items *determinar la dimensiones cota medida entre los elementos*
	screwdriver *el destornillador*	Tighten or loosen screw *apretar o aflojar tornillos*
	saw *el serrucho*	cut material (wood, metal, etc.) *material decorte de la (madera, metal, etc.)*
	file (rasp) *la lima*	smooth rough surfaces, remove metal/wood splinters *lisas superficies rugosas, eliminar astillas de metal*
	drill *el taladro*	put a hole in an item *Ponga un agujero en un artículo*
	screws *los tornillos*	attach items together *adjuntar elementos juntos*

Appendix G

Usability Metrics Tools

Instructions, items, and rating options read verbally in Spanish.

User Satisfaction Rating: After-Scenario Questionnaire (Lewis, 1995)

Please rate the usability of the training between 1-5 Overall, I am satisfied with:	1: Strongly Disagree	2: Disagree	3: Neutral	4: Agree	5: Strongly Agree
the ease of completing this task.					
the amount of time it took to complete this task.					
the support information received when completing this task.					

Adapted Learning Value and Self-Efficacy Scale (Artino & McCoach, 2008)

	1: Strongly Disagree	2: Disagree	3: Neutral	4: Agree	5: Strongly Agree
1) It was personally important for me to perform well in this project.					
2) This project provided me a great deal of practical information.					
3) I was very interested in the content in this project.					
4) It was important for me to learn how to do this project.					
5) The knowledge I gained in this project can be applied to future projects.					
6) Even in the face of technical difficulties, I am certain I can learn the material using this method of teaching.					
7) I am confident I can learn without an instructor present to assist me.					
8) I am confident I can do an outstanding job on activities using this method of instruction.					
9) I am certain I can understand the most difficult materials presented using this method of instruction.					
10) Even with distractions, I am confident I can learn lessons using this method of instruction.					

Appendix H

Instructional Clarity Feedback Form

Each instruction or question was verbally provided to applicants in Spanish.

1. On the pictorial action instructions that you used to construct this project, please circle any steps, or transitions between step, that you feel are unclear.
2. Please specify how you feel that these steps or transitions could be improved.
3. Are there any steps that you feel should be added to improve clarity? If so, which ones?
4. Are there any steps that you feel should be removed to improve clarity? If so, which ones?
5. Are there any items shown in the illustrations that you feel should be modified for clarity? If so, which ones? How?

Final Version of Pictorial Action Instructions
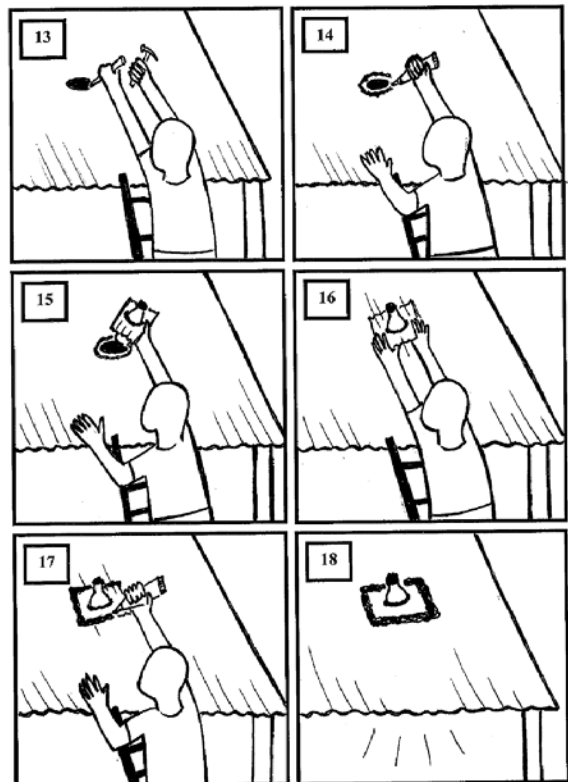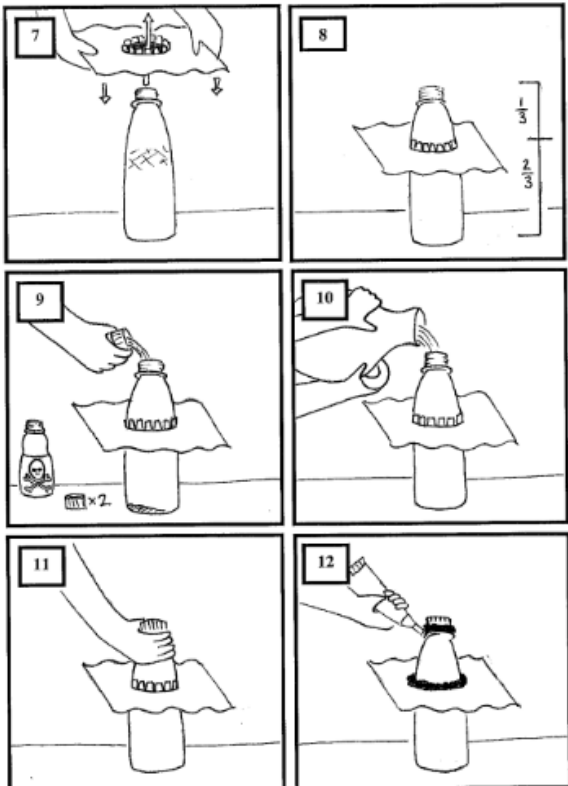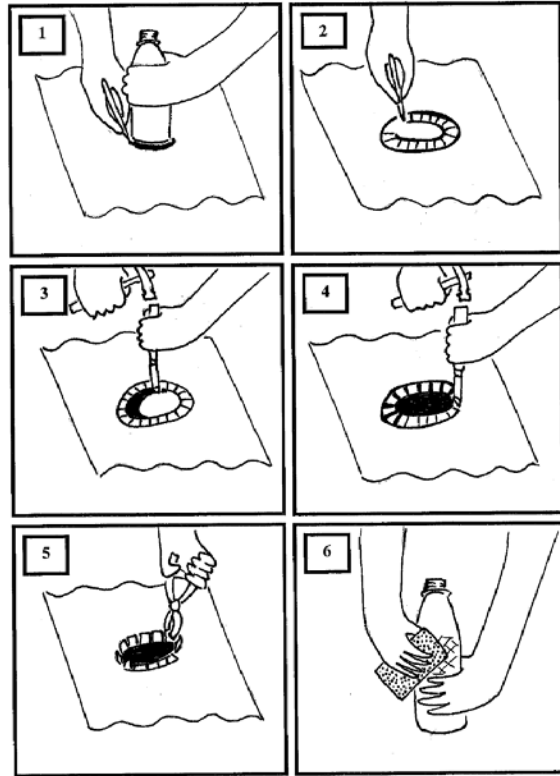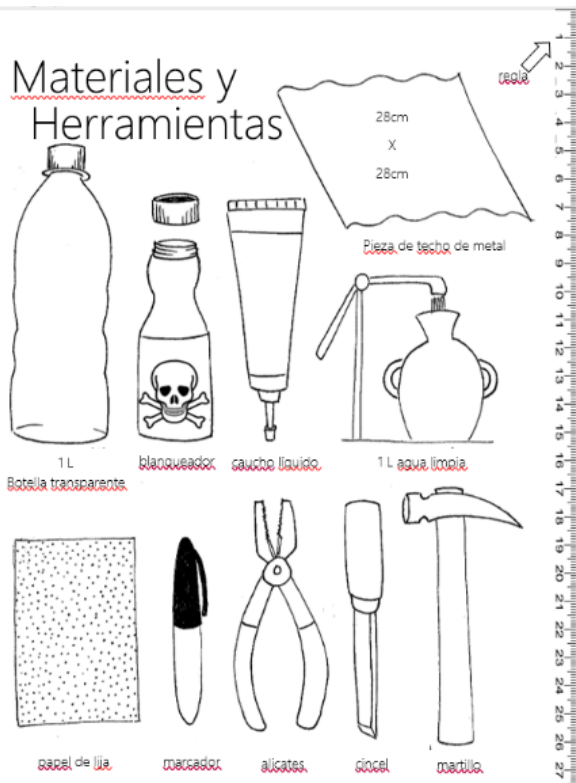
Appendix J

IRB Approval Letter for Study in Manuscript 2

UNLV

UNLV Biomedical IRB - Administrative Review

Notice of Excluded Activity

DATE: December 21, 2016
TO: Du Feng, PhD
FROM: UNLV Biomedical IRB
PROTOCOL TITLE: [993244-1] Pictorial action instructions to train low-literacy populations to construct a basic humanitarian engineering project: A feasibility study
SUBMISSION TYPE: New Project
ACTION: EXCLUDED - NOT HUMAN SUBJECTS RESEARCH REVIEW
DATE: December 21, 2016
REVIEW TYPE: Administrative Review

Thank you for your submission of New Project materials for this protocol. This memorandum is notification that the protocol referenced above has been reviewed as indicated in Federal regulatory statutes 45CFR46.

The UNLV Biomedical IRB has determined this protocol does not meet the definition of human subjects research under the purview of the IRB according to federal regulations. It is not in need of further review or approval by the IRB.

We will retain a copy of this correspondence with our records.

Any changes to the excluded activity may cause this protocol to require a different level of IRB review. Should any changes need to be made, please submit a Modification Form.

If you have questions, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 702-895-2794. Please include your protocol title and IRBNet ID in all correspondence.

Office of Research Integrity - Human Subjects
4505 Maryland Parkway . Box 451047 . Las Vegas, Nevada 89154-1047
(702) 895-2794 . FAX: (702) 895-0805 . IRB@unlv.edu

UNLV

UNLV Biomedical IRB - Expedited Review Approval Notice

DATE: July 21, 2017
TO: Du Feng, PhD
FROM: UNLV Biomedical IRB
PROTOCOL TITLE: [1067871-1] Evaluating the Use of Pictorial Action Instructions to Train Low Literacy Individuals to Construct a Basic Humanitarian Engineering Project
SUBMISSION TYPE: New Project
ACTION: APPROVED
APPROVAL DATE: July 21, 2017
EXPIRATION DATE: July 20, 2018
REVIEW TYPE: Expedited Review

Thank you for submission of New Project materials for this protocol. The UNLV Biomedical

IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit

ratio and a protocol design wherein the risks have been minimized. All research must be

conducted in accordance with this approved submission.

PLEASE NOTE:

Upon approval, the research team is responsible for conducting the research as stated in the

protocol most recently reviewed and approved by the IRB, which shall include using the most

recently submitted Informed Consent/Assent forms and recruitment materials. The official

versions of these forms are indicated by footer which contains approval and expiration dates. If

your project involves paying research participants, it is recommended to contact Carisa Shaffer,

ORI Program Coordinator at (702) 895-2794 to ensure compliance with subject payment policy.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through ORI - Human Subjects. No changes may be made to the existing protocol until modifications have been approved.

ALL UNANTICIPATED PROBLEMS involving risk to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NONCOMPLIANCE issues or COMPLAINTS regarding this protocol must be reported promptly to this office.

This protocol has been determined to be a Minimal Risk protocol. Based on the risks, this protocol requires continuing review by this committee on an annual basis. Submission of the **Continuing Review Request Form** must be received with sufficient time for review and continued approval before the expiration date of July 20, 2020.

If you have questions, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 702-895-2794. Please include your protocol title and IRBNet ID in all correspondence.

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    workers.pdf

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    http://who.int/healthy_settings/types/en/

<div align="center">**Curriculum Vitae**</div>

<div align="center">**KATHLEEN PACO CADMAN, MSN, RN, CNE**</div>

<div align="center">kathleencadman@weber.edu</div>

EDUCATION

Doctorate of Philosophy – Nursing	University of Nevada, Las Vegas	2015-2018
Master of Science – Nursing	Western Governors University	2011-2012
Master of Science – Nursing	Western Governors University	2010-2011
Bachelor of Fine Arts – Studio Art	Graceland University	1997-2002

ACADEMIC & RELATED EMPLOYMENT

Assistant Professor of Nursing	Weber State University	2013-Present
Director of Nursing	Aspen Care Center	2011-2013
Clinical Supervisor for Pediatrics	Maxim Healthcare Services	2010-2011
Community Health Educator	World Service Corp – India	2010
Health Worker Educator	Health Ministries Assoc.- Guatemala	2009
Health Worker Educator	Hope for the Himalayas- Nepal	2007
Reproductive Health Educator	GanSu ZhengFa University- China	2003-2005

PUBLICATIONS

Cadman, K. P. & Feng, D. (2018). *Using pictorial action instructions to build a basic humanitarian engineering project: A randomized control trial.* Manuscript in preparation, School of Nursing, University of Nevada, Las Vegas.

Cadman, K. P. & Feng, D. (2018). *Development and usability testing of pictorial action instructions: A feasibility study*. Manuscript in preparation, School of Nursing, University of Nevada, Las Vegas.

Cadman, K. P. (2017). Lay worker health literacy: A concept analysis and operational definition. *Nursing Forum, 52*(4), 348-356. doi:10.1111/nuf.12203

Cadman, K. (2016). Safety. In Dalhkemper, T. (Ed.), *Caring for Older Adults Holistically* (6th ed.). Philadelphia, PA: F.A. Davis Company.

RESEARCH PROJECTS

Tactics for Teaching Evidence-based Practice. Weber State University   2015-2016
360 BSN students enrolled in Evidence-based Practice course evaluated

Primary Health Concerns Identified for Boane District, Mozambique.   2015
Needs-Based Assessment of 138 homes (748 individuals)

Assessing and Addressing the Lack of Education Materials for Indigenous   2014-2015
Rural Health Workers (RHW). Interviewed 14 RHWs in Mali & Ghana.

Recruitment, Training, and Retention: Addressing the Educational Barriers to   2013-2014
a Sustainable Global Health Workforce. Interviewed 12 RHWs in Mozambique

PRESENTATIONS

Using Pictorial Action Instructions to Train Low-Literacy Adults to Construct a   April 2018
Basic Humanitarian Engineering Project [Poster]. Western Institute of Nursing
Research Conference. Spokane, WA. Co-presenter Dr. Du Feng.

Sick of it All: The Struggle for Equal Healthcare Across Diverse Populations   Oct 2016
[Podium]. 18th Annual Diversity Conference: Weber State University, UT.

Tailoring Curriculum to the Individual: Increasing Student Engagement   Sept 2016
from Elementary through University [Podium & Interactive Workshop].
Families Alive Conference: Weber State University, UT.

Action Plan to Improve the Future Global Burden of Disease [Podium].   March 2016
Southern Association for the History of Medicine & Science 18th Annual
Conference: University of Nevada, Las Vegas, NV.

Recruitment, training and retention: Addressing educational barriers to a   July 2014
sustainable global health workforce in rural communities [Poster]. Nurse
Educators' Conference [National]: Breckenridge, CO.

HONORS & AWARDS

Community Engaged Faculty Member of the Year: Weber State University   2018

Jonas Philanthropies-Nurse Leader Scholars Recipient: $20,000   2016-2018

Tish M. Smyer Nursing Dissertation Award Recipient: $1,200   2017

Yaffa Dahan Nursing Dissertation Award Recipient: $1,200   2017

Weber State University Center for the Study of Poverty and Inequality: $4,200   2016

Northern Utah *40 Under 40* Recipient: Recognized for community engagement   2015
      http://events.standard.net/kathleen-cadman-forty-under-40/

RSPG New Faculty Grant Recipient: Weber State University: $1,440   2015

DCHP Professional Development Marriott Grant Recipient: $2,500   2014