Improving Sustainability in WaSH by Integrating Implementation Science: A Review of Implementation Outcomes in Rural Drinking Water Systems in Low- and Middle-Income Countries

By

Christine Pettitt-Schieber

A Master's Paper submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Masters of Public Health in the Public Health Leadership Program

Spring 2017

Approved by:

Lori A. Evarts, MPH PMP CPH **Date**

Rohit Ramaswamy, PhD MPH **Date**

ABSTRACT

Background: Despite the magnitude of resources invested in providing access to clean drinking water in rural areas of low- and middle-income countries (LMIC), sustainability of the myriad solutions available remains elusive. Issues of implementation significantly limit the potential impact of these systems on health outcomes. Existing linkages shown between implementation quality and health outcomes demonstrate the powerful impact of implementation science on sustainability. This paper assesses the extent to which implementation science is currently being used to implement drinking water interventions in LMIC.

Methods: A literature review was conducted to determine if any study has directly used an implementation science approach. Finding no relevant articles, a second literature review was undertaken to determine which implementation outcomes are current being addressed in implementing these interventions. Implementation outcomes were translated to approximate their representation in drinking water system interventions.

Results: Sixteen (n=16) studies show evidence of attention to implementation outcomes. Outcomes with the greatest representation in studies were Acceptability, Appropriateness and Adoption (81%-94%), while Penetration, Cost, Feasibility and Fidelity ranged from 25-63% representation. Sustainability was evaluated in 0% of studies.

Discussion: The range of results shows that implementation outcomes are only partially integrated into this sector, to the detriment of achieving the Sustainable Development Goals. Resolving this gap will require a concentrated effort by both practitioners and researchers. Consequently, implementation outcomes are translated here into outcomes appropriate to drinking water system interventions, and a research agenda for the sector is proposed for the future inclusion of implementation science.

KEYWORDS: Implementation science, drinking water systems, WaSH, LMIC, sustainability

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS

DALY	Disability-Adjusted Life Year
HWTS	Household Water Treatment and Storage
ILLiad	Inter-Library Loan program
IS	Implementation Science
IWRM	Integrated Water Resources Management
JMP	Joint Monitoring Programme for Water Supply and Sanitation
LMIC	Low and Middle Income Countries
MDGs	Millennium Development Goals
NIH	National Institutes of Health
SDGs	Sustainable Development Goals
SODIS	Solar Energy Disinfection of Water
UNICEF	United Nations Children’s Fund
WaSH	Water, Sanitation and Hygiene
WHO	World Health Organization
WSP	Water Safety Planning

Introduction

In the search for a sustainable solution to poverty alleviation on a global scale, access to the basic human need for water is appropriately high on the list. It remains elusive, as attempts succeed and fail in a variety of different settings, under a variety of circumstances. The fields of public health and education have begun to embrace implementation science to improve the rates of success, both lengthening the duration an intervention is used and improving its uptake by users and their communities. This paper makes the case for the application of these methods to improve the sustainability of the innovative technologies and systems used to deliver clean water in rural areas of low- and middle-income countries. As part of that application, further research is recommended, including the development of indicators measuring implementation outcomes.

Background

In 1990, unsafe water and sanitation were determined to be responsible for 5.3% of global deaths and 6.8% of disability-adjusted-life-years (DALYs) (Murray, Lopez, & others, 1996). Many of these individuals lived in rural and remote communities, often considered the "last mile" of supply chain delivery and consequently the most challenging constituents to reach. These communities were often unable to connect to a municipal water supply available for their urban counterparts, nor are the parts and labor required for maintenance readily accessible. Since then, water, sanitation and hygiene (WaSH) technical experts and ministries of health have been attempting to provide these unique communities with access to safe drinking water for decades. Tanzania, for example, placed rural access to safe water on the ruling party's agenda in 1971, aiming to achieve their goal by 1991 (Therkildsen, 1988). India established a similar goal nearly two decades prior with their First Five Year Plan in 1951 (Khurana & Sen, 2008). These goals remained the initiative of individual countries of their own volition, distinct from a global movement until 2000.

In 2000, upon the creation of the Millennium Development Goals (MDGs), global attention was heightened on provision of clean, safe water as part of MDG target 7.c, which declared the world would “halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation” (World Health Organization, n.d.). Achieving this goal required new systems for monitoring progress, resulting in the establishment of the Joint Monitoring Programme (JMP) by the World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF), (“WHO / UNICEF Joint Monitoring Programme: mission & objectives,” n.d.). Through the work of the JMP and its partners, 91% of the world’s population now has access to improved water sources (World Health Organization & UNICEF, 2015). These interventions are numerous in their use of technology and diverse in their complexity. Interventions included household filtering technology such as biosand filters; boreholes; public hand pumps established in a central location; household taps; and piped water systems, like photovoltaic (solar-powered) pumps that pipe water from underground water tables to public and private taps.

Just how well did we achieve the MDG 7.c? While 2.6 billion people newly have access to improved drinking water sources since 1990, over 15% of rural inhabitants and 663 million people total remain without this access (WHO 2015). According to the JMP report, “159 million people still use surface water, and two-thirds live in sub-Saharan Africa” (World Health Organization & UNICEF, 2015, p.11). As we move into the era of the Sustainable Development Goals (SDGs), notable changes have been made to the goals for clean drinking water. First, a single SDG (SDG 6) is dedicated to this area, whereas in the MDGs it was under the broader category of environmental sustainability. Second, following the passing of United Nations Resolution 64/292 in July 2010, clean drinking water is now recognized as a human right (United Nations, 2014). Finally, the goal has been expanded to “ensure access to water and sanitation for all” (Nino, n.d.). This more expansive goal includes supporting communities in expanding their capacity to manage improved water sources. However, this more advanced and nuanced focus on clean drinking water does not fully address the question of “how” these goals will be achieved and the question of sustainability. The field of global health is rife with examples of good ideas not being implemented well. An example is the PlayPump, described in the case study below.

Case Study: PlayPumps International

In the late 1990s, former advertising executive Trevor Field invented a solution for water-scarce communities to collect water more efficiently, more effectively and, most importantly, with minimal “work”. His invention, PlayPumps, connected a piece of children’s playground equipment known as a roundabout to a water pump. The design was based on the premise that children would use the equipment for pleasure, and simultaneously pump water from the ground into a tank. The structure holding the tank aloft had four panels for advertisements that would generate revenue for pump maintenance. The ingenuity of the design was apparent to all supportive stakeholders: by incorporating a piece of children’s play equipment to the water pump, the menial labor involved in fetching water every day is removed; water is instead pumped and collected as a natural by-product of children’s desire to play.

By 2006, PlayPumps were in South Africa and Mozambique and were gaining global notoriety. The World Intellectual Property Organization lauded them as brilliant (World Intellectual Property Organization, n.d.) and the World Bank awarded them the 2000 World

Bank Development Marketplace Award (Zenios et al., 2012). Donors pledged millions of dollars towards the expansion of PlayPumps, including the Clinton Foundation, First Lady Laura Bush, and private donors such as the Case Family (Zenios et al., 2012). Journalists were all too happy to report on something so positive in the global effort to reduce poverty (FRONTLINE/World, 2010).

By 2010, PlayPumps were declared a failure. An 89-page report from the Swiss Resource Centre and Consultancies for Development on PlayPumps in Mozambique outlined numerous issues in the pumping system, the amount of water, and actual usage of the play equipment (Obiols & Erpf, 2008). As it turned out, the children playing were not generating enough water, and they often were not playing – leaving the women of the community to turn the roundabout equipment instead (Zenios, 2012). PlayPumps, once hailed as a groundbreaking intervention, had failed to be the panacea for sustainable clean water delivery for which the world was desperate.

The issues with PlayPumps were numerous. They were financially unsustainable, costing $14,000 per project (Campana, 2010), they were not appropriate for every context, and they were unacceptable to communities as a primary method of drawing water after the initial implementation. PlayPumps is not alone, however, as a failed attempt to provide millions of rural inhabitants with clean drinking water in creative, innovative ways, often using new technology. Many drinking water supply projects incorporate interventions that have proven to work in pilot programs, yet are unable to withstand the test of time. These interventions may work initially, but fail to achieve sustainability, as defined by the "continued delivery of safe drinking water and its benefits to a population without resource depletion" (Amjad, Ojomo, Downs, Cronk, & Bartram, 2015, p. 1499).

The resources engaged in attempting to solve this issue of both potable water delivery and continued service are considerable. Billions of dollars have been invested in the WaSH sector, a significant portion of which has been dedicated to providing communities in low and middle-income countries (LMIC) with drinking water free of pathogens. The PlayPumps example demonstrates that sustainability is, at its core, a function of quality implementation. Fortunately, work has been done in the past several years to research methods that can improve the quality of implementation. These methods are known under the broad umbrella of the field of implementation science.

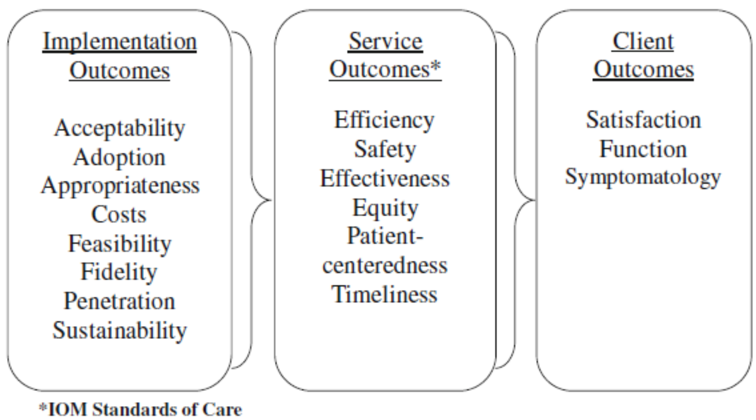
Overview: Implementation Science

Implementation science (IS) is an approach predicated on systems thinking, defined as "the study of methods to promote the integration of research findings and evidence into healthcare policy and practice" (National Institutes of Health [NIH], Fogarty International Center, n.d., para.1). In a 2008 systematic review, Durlak and DuPre demonstrated the strong connection between IS and program outcomes in the fields of health and education (Durlak & DuPre, 2008). For example, one meta-analysis included in their review demonstrated that in drug prevention programs "reporting proper implementation registered an effect size of 0.34 greater than those reporting improper implementation" (Tobler, 1986, p. 550). Durlak & DuPre's review of 542 studies concluded that "the level of implementation achieved is an important determinant of program outcomes" (2008, p. 334).

The core components of IS are determinants, strategies, outcomes and frameworks. Implementation science incorporates a sophisticated and complex view of the factors influencing implementation in each unique context, paying close attention to facilitators and barriers at multiple levels. These include individual, communal, societal and political elements of the implementation context and environment (Krause et al., 2014). IS strategies are the methods by which interventions are moved into practice while ameliorating barriers and leveraging facilitators. Proctor, Powell & McMillen define these as “methods or techniques used to enhance the adoption, implementation, and sustainability of a clinical program or practice” (Proctor, Powell, & McMillen, 2013). To address the many challenges and to best capitalize on enabling factors, the most effective implementation strategies will be both multi-level and multifaceted (Aarons, Hurlburt, & Horwitz, 2011). Over time, frameworks have been developed to suggest which variables might affect implementation outcomes, and in which direction (Nilsen, 2015). These are useful to directing our work so that our attention is strategically placed on the right determinants, our strategies are purposefully developed, and our implementation outcomes are carefully selected, all based on our desired health outcomes. Integrating IS into the processes and systems of a sector is critical to creating evidence on how best to implement these processes and systems for effective and sustainable outcomes.

A start to integrating IS into a project, program or sector is by defining implementation outcomes, building knowledge of which are most important, and understanding how they relate. Implementation outcomes, first defined by Proctor et al. in 2011, are proximal outcomes that influence service or client/beneficiary outcomes (Proctor, Silmere, Raghavan, Hovmand, Aarons, Bunger, ... & Hensley, 2011). They represent “effects of deliberate and purposive actions to implement new treatments, practices, and services” (Proctor, et al., 2011, p. 65), which can serve as indicators along the path of implementing an intervention. In addition, they “advance understanding of implementation processes, enable studies of the comparative effectiveness of implementation strategies, and enhance efficiency in implementation research” (Proctor, et al., 2011, p. 65). Figure 1 shows the framework for implementation outcomes and the eight constructs that define implementation outcomes (Proctor, et al., 2011). In relation to clean drinking water, achievement of these outcomes would result in “Client Outcomes,” which include community satisfaction, functionality of the water system or filtration device, and access to the water.

Figure 1. Implementation Outcomes Framework



Source: Proctor, E., Silmere, H., Raghavan, R., Hovmand, P., Aarons, G., Bunger, A., ... & Hensley, M. (2011).

The integration of implementation science has not yet occurred to the extent it could in the WaSH sector, specifically in the delivery and implementation of clean water delivery systems in LMIC. It is important that we understand where implementation science can be adapted to fit this sector, what tools are relevant and how they can be applied, and what data needs to be collected to establish implementation indicators. This paper conducts a literature review to assess the extent to which implementation science is being employed in the water sector, and suggests a research agenda to advance the use of IS in this sector.

Methods

A literature search was undertaken to determine whether implementation science has been used in published studies on the delivery of clean water in rural areas of developing countries. This search was limited to peer-reviewed articles, available at no cost, written in English and published after 2000. This date limitation corresponds to when the first global programs were established in response to the Millennium Development Goals. The keywords searched in Scopus, PubMed, Global Health databases and *Implementation Science* are provided in Table 1. These criteria resulted in ten articles. The inclusion criteria required studies to describe a drinking water intervention for a rural area in a low- or middle-income country. Upon screening the titles, zero (n=0) met the inclusion criteria. The results can be seen in Table 1.

Table 1. Initial Literature Review Search Terms and Results

Database	Search Terms	Results	Relevant Titles
Scopus	TITLE-ABS-KEY (“implementation science” AND “water”)	10	0
Global Health	All Text (“implementation science” AND “water”)	2	0
PubMed	"implementation science"[All Fields] AND "water"[All Fields]	6	0
Implementation Science	Searched in Scopus: (SRCTITLE ("Implementation Science") AND TITLE-ABS-KEY (water))	1	0

Failing to find literature meeting the noted inclusion criteria, a second search was conducted using modified search terms that expanded the search to include IS outcomes that may have been defined in terms that are different from those used in traditional implementation science research. As before, the Scopus, PubMed and Global Health databases and *Implementation Science* were searched to identify articles based on the defined keywords provided in Table 2.

Table 2. Second Literature Review Search Terms

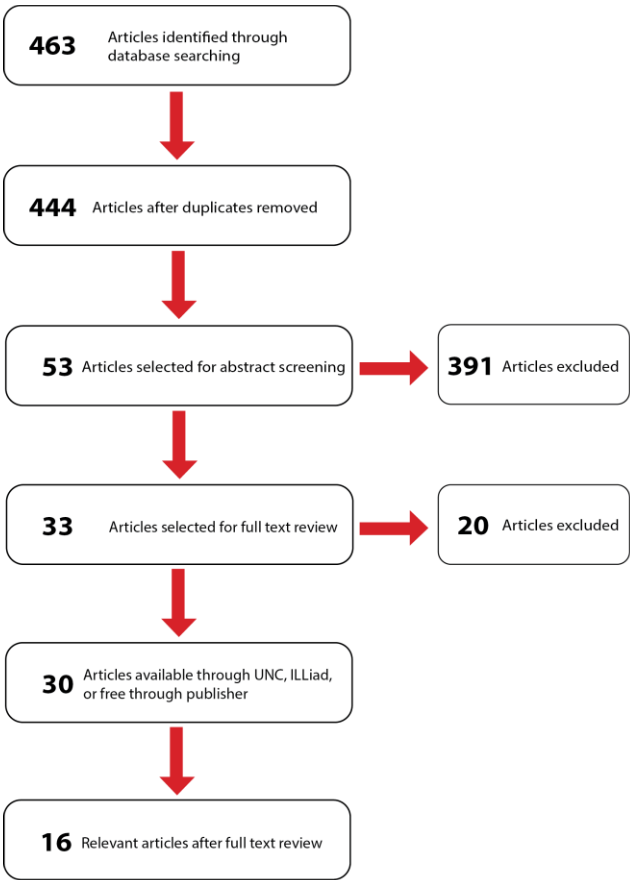
Source	Search Terms
Scopus	TITLE (water) AND (TITLE (implement*) OR KEY (implement*)) AND TITLE-ABS-KEY (sustain* OR scale-up OR adaptation OR iwrm OR "integrated water resources management") AND (LIMIT-TO (SRCTYPE,"j ")) AND (EXCLUDE (PUBYEAR,1999) OR EXCLUDE (PUBYEAR, 1998) OR EXCLUDE (PUBYEAR, 1997) OR EXCLUDE (PUBYEAR, 1995) OR EXCLUDE (PUBYEAR, 1986)) AND (LIMIT-TO (LANGUAGE,"English "))
PubMed	(water[Title] AND (implement[Title] OR implementability[Title] OR implementable[Title] OR implementation[Title] OR implementing[Title])) AND (sustainable[Title/Abstract] OR sustainability[Title/Abstract] OR sustained[Title/Abstract] OR scale-up[Title/Abstract] OR adaptation[Title/Abstract] OR iwrm[Title/Abstract] OR "integrated water resources management"[Title/Abstract]) AND English[lang] AND ("2000/01/01"[PDAT] : "2017/12/31"[PDAT])
Global Health	(TITLE (water) AND (TITLE (implement*) OR KEY (implement*)) AND TITLE-ABS-KEY (sustain* OR scale-up OR adaptation OR iwrm OR "integrated water resources management"))
Implementation Science	Searched in Scopus: (SRCTITLE ("Implementation Science") AND TITLE-ABS-KEY (water))

Search results were screened by title and then by abstract before being selected for a full-text review. In some cases, full-text reviewed articles were determined to be irrelevant upon further reading. At each stage, inclusion criteria required articles to present or evaluate the implementation of water systems or projects in rural areas in low- and middle-income countries (LMIC), with some part or all of the intervention intended to generate safe drinking water. Articles eliminated did not meet one or more of these criteria.

Results

The second search identified a total of 463 articles. 19 of these were found to be duplicates, reducing the number to 444. After screening 444 titles and 53 abstracts, 33 articles were selected for full-text review. Three of the 33 articles were unavailable through the University of North Carolina Library, the Inter-Library Loan program (ILLiad), or free from the articles' publishers. After a full-text review of 30 articles, it was determined that 16 of the available articles refer to implementation outcomes in their review of a drinking water intervention in rural areas of LMIC. Figure 2 depicts this process.

Figure 2. Literature Review Process



Of the 16 relevant articles, five reviewed interventions in multiple countries, two reviewed interventions in India, and the remainder centered on programs in various other countries. The reported interventions included sand-based filters, Integrated Water Resources Management (IWRM), Water Safety Planning (WSP), and other methods of drawing or purifying water safe for drinking.

Based on my understanding of implementation science terminology and the terminology used in the relevant articles, a translation was conducted to redefine the published data into implementation science terminology. For example, Ngai and Fenner (2014) describe the challenges of implementation cost and adoption of biosand filters because the implementing organization no longer wants to subsidize the cost, yet the filters are too expensive for households to pay full price, thus tapering new installations of the filters. Similarly, an example of acceptability is the discussion in Brunson et al. (2013) of culturally-appropriate solutions; if a community "believes drinking warm water causes illness, then setting up a system that…results in warm drinking water may produce water that is safe but is deemed unacceptable to the community" (Brunson, Busenitz, Sabatini, & Spicer, 2013, p. 490). Articles were thus reviewed through this lens of translated outcomes.

Translating Implementation Outcomes into Water Systems

Translating implementation outcomes into terms applicable to the delivery of clean drinking water is an integral component of determining strategies to implement with quality. Measuring implementation outcomes in a specific sector first requires clear definitions. Appropriate definitions for implementation outcomes of drinking water system interventions have been summarized in Table 3.

Table 3. Implementation Outcome Equivalents for Drinking Water Systems

Implementation Outcome	Definition from Proctor, et al. 2011	Water system equivalent outcome
Acceptability	perception among implementation stakeholders that a given treatment, service, practice, or innovation is agreeable, palatable, or satisfactory	Expressed desire from community to bring in the proposed method for filtering or drawing clean water. Community members believe the water is safe to drink. Implementation is permitted in the community.
Adoption	intention, initial decision, or action to try or employ an innovation or evidence-based practice; Adoption also may be referred to as ‘‘uptake.’’	Implementation is embraced by the community by regular usage of the technology or system, and it is the primary source or method of cleaning water for drinking.
Appropriateness	perceived fit, relevance, or compatibility of the innovation or evidence-based practice for a given practice setting, provider, or consumer; and/or perceived fit of the innovation to address a particular issue or problem	Does not directly conflict with ideologies, principles or practices in the community. Community requires a method for drawing or purifying water for drinking.
Cost	cost impact of an implementation effort	Individuals can afford to use the intervention, and the individuals or community can afford to repair or replace the system or technology when necessary.
Feasibility	extent to which a new treatment, or an innovation, can be successfully used or carried out within a given agency or setting	Users have the capacity to implement the technology or system, and the local partner agency (e.g. ministry of water, NGO) has the capacity to collaborate with and support users to implement the intervention
Fidelity	degree to which an intervention was implemented as it was prescribed in the original protocol or as it was intended by the program developers	The intervention is implemented as designed or used in pilot studies, and/or users are correctly using the technology or system
Penetration	integration of a practice within a service setting and its subsystems	Additional users beyond the initial intervention group are using the technology or system, whether due to purposeful expansion of the intervention or uptake from word of mouth
Sustainability	extent to which a newly implemented treatment is maintained or institutionalized within a service	Whether the means exist within or nearby the community to source parts and labor for maintenance,

Implementation Outcome	Definition from Proctor, et al. 2011	Water system equivalent outcome
	setting’s ongoing, stable operations	whether the community has the funding to procure such resources, and the length of time beyond the initial implementation that individuals continue to use the filters or water system. Can also include whether a governing body is successfully maintaining operation of the system, including successfully transitioning leadership of the body when necessary. Can include scale-up.

Based on this translation process, four articles included discussion of four or fewer implementation outcomes, seven articles included five to six outcomes, and five articles included seven outcomes. Zero included all eight outcomes. Acceptability and appropriateness were present in 15 of the articles, adoption was discussed in 13, cost and feasibility in ten, fidelity in eight, penetration in four, and sustainability in zero. Table 4 shows the distribution of implementation outcomes in the search results.

Table 4. Distribution of Implementation Outcomes in Search Results

Implementation Outcome	Percent of Search Results Describing This Outcome (Total = 16)
Acceptability	94% (n=15)
Appropriateness	94% (n=15)
Adoption	81% (n=13)
Cost	63% (n=10)
Feasibility	63% (n=10)
Fidelity	50% (n= 8)
Penetration	25% (n=4)
Sustainability	0% (n=0)

Table 5 shows the number of outcomes found in each article, and Table 6 elaborates on which outcomes, types of interventions and countries were discussed in each article.

Table 5. Percent of Implementation Outcomes Present in Search Results by Article

Article	Percent of Implementation Outcomes
Borde, 2016	88%
Brunson, Busenitz, Sabatini, & Spicer, 2013	88%
Ncube & Pawandiwa, 2013	88%
Ngai & Fenner, 2014	88%
Ojomo, Elliott, Goodyear, Forson, & Bartram, 2015	75%
Peter & Nkambule, 2012	63%
Raghavan, Chockalingam, & Johar, 2013	63%
Barnes, Ashbolt, Roser, & Brown, 2014	50%
Casanova, Walters, Naghawatte, & Sobsey, 2012	50%
Khatri, Iddings, Overmars, Hasan, & Gerber, 2011	50%
Mangoua-Allali, Coulibaly, Ouattara, & Gourene, 2012	50%
Penning de Vries, 2007	50%
Suhardiman, Clement, & Bharati, 2015	50%
Clark, Pinedo, Fadus, & Capuzzi, 2012	38%
Gallego-Ayala & Juízo, 2011	25%
Holm, 2012	25%

Table 6. Table of Results by Article, Country, Water Intervention and IS Outcomes

Article	Source	Country	Type of Intervention	Implementation Outcomes Discussed
Barnes, Ashbolt, Roser, & Brown, 2014	Scopus	Multiple	Multiple	Acceptability, Adoption, Appropriateness, Feasibility
Borde, 2016	Scopus	Multiple	Solar Energy Disinfection of Water	Acceptability, Adoption, Appropriateness, Cost, Feasibility, Fidelity, Penetration
Brunson, Busenitz, Sabatini, & Spicer, 2013	Scopus	Multiple	Multiple	Acceptability, Adoption, Appropriateness, Cost, Feasibility, Fidelity, Penetration
Casanova, Walters, Naghawatte, & Sobsey, 2012	Scopus	Sri Lanka	Ceramic water filters	Acceptability, Adoption, Appropriateness, Fidelity
Clark, Pinedo, Fadus, & Capuzzi, 2012	Scopus	Kenya	Slow-sand water filters	Acceptability, Appropriateness, Cost
Gallego-Ayala & Juízo, 2011	Scopus	Mozambique	IWRM	Appropriateness, Feasibility
Holm, 2012	Scopus	Malawi	*Unspecified*	Acceptability, Adoption
Khatri, Iddings, Overmars, Hasan, & Gerber, 2011	Global Health	Pacific Islands	Water Safety Planning	Acceptability, Appropriateness, Cost, Fidelity
Mangoua-Allali, Coulibaly, Ouattara, & Gourene, 2012	Global Health	Côte d'Ivoire	Biosand Water Filters	Acceptability, Adoption, Appropriateness, Cost
Ncube & Pawandiwa, 2013	Global Health	South Africa	Water Safety Planning	Acceptability, Adoption, Appropriateness, Cost, Feasibility, Fidelity, Penetration
Ngai & Fenner, 2014	Scopus	India	Biosand Water Filters	Acceptability, Adoption, Appropriateness, Cost, Feasibility, Fidelity, Penetration
Ojomo, Elliott, Goodyear, Forson, & Bartram, 2015	Scopus	Multiple	Household Water Treatment and Storage	Acceptability, Adoption, Appropriateness, Cost, Feasibility, Fidelity

Article	Source	Country	Type of Intervention	Implementation Outcomes Discussed
Penning de Vries, 2007	Scopus	Multiple	Multiple Use Systems	Acceptability, Adoption, Appropriateness, Cost
Peter & Nkambule, 2012	Scopus	Swaziland	Multiple	Acceptability, Adoption, Appropriateness, Cost, Feasibility
Raghavan, Chockalingam, & Johar, 2013	Global Health	India	Underground pump with community storage and taps	Acceptability, Adoption, Appropriateness, Feasibility, Fidelity
Suhardiman, Clement, & Bharati, 2015	Scopus	Nepal	IWRM	Acceptability, Adoption, Appropriateness, Feasibility

Discussion

As described earlier, it is well-established that WaSH projects have issues with sustainability (e.g., PlayPumps). As shown by the literature reviews undertaken concerning drinking water solutions for rural areas in LMICs, there is evidence that the lack of sustainability may be a result of issues with the implementation of these projects. An implementation science approach to such WaSH projects may be useful to study systematically (i) whether implementation outcomes are being achieved, (ii) barriers to achieving these outcomes and (iii) appropriate implementation strategies. As demonstrated, the initial literature review using classical "implementation science" terms did not result in any relevant peer-reviewed articles, indicating that the IS field is new to the WaSH sector. However, the second literature review revealed, through the content examination of the sixteen identified articles, that WaSH researchers have been evaluating implementation issues. These peer-reviewed articles were found when search terms that included "implementation," "drinking water," and "sustainability" were used, indicating a basic, non-systematic understanding that implementation has an association with sustainability. What follows is an analysis of how each outcome was represented in the search results, its appropriate translation into drinking water interventions in rural LMIC settings, and noted patterns or trends in the literature.

Acceptability (n=15)

Using the IS framework described in Proctor, "acceptability" as an implementation outcome is the expressed desire from community to introduce the intervention as a possible solution. Translated into terms appropriate for clean drinking water, this would be an expressed desire from the community to bring in the proposed method for filtering or drawing clean water.

Users must believe that the water is safe to drink and allow implementation of the intervention in their community.

Acceptability was evident in almost all of the articles identified in the second literature search; the one exemption being the article by Gallego-Ayala & Juízo, 2011, which was an Integrated Water Resource Management (IWRM) project conducted in Mozambique. Given that the IWRM strategy is called out specifically in the SDGs (Target 6.5) (Nino, n.d.) it is perhaps unsurprising that the acceptability of this strategy to a country or community is assumed and omitted from evaluation.

Appropriateness (n=15)

As defined by Proctor, "appropriateness" is a measure of whether this intervention is a fit for this community, so implementers can accurately determine, regardless of the evidence base for this intervention, whether it will be a fit with the community's values and lifestyle. Translated into water systems, appropriateness considers whether the community needs an improved method for clean drinking water and whether the proposed method directly conflicts with ideologies, principles or practices in the community. Nearly all studies (94%) reviewed the appropriateness of interventions to the local community and context.

Adoption (n=13)

Adoption – a demonstrated interest in uptake of the intervention – is then the embracing of the intervention through regular or exclusive usage of the intervention for drinking water.

Understanding barriers to uptake is now more commonplace, as shown by the 81% of studies that assessed adoption. As stated by Borde, "a growing number of water researchers have gravitated toward cognitive and behavioral theories of behavioral change" (p. 493) to understand the adoption of technology better. Adoption, however, is necessary but insufficient to achieving sustainability. Several of the studies assume is that if a program is “community-owned,” meaning the community takes ownership of the project at an early stage, this will result in long-term usage (Clark, Pinedo, Fadus, & Capuzzi, 2012; Holm, 2012; Mangoua-Allali, Coulibaly, Ouattara, & Gourene, 2012; Penning de Vries, 2007). This faulty logic skips several key outcomes, including feasibility, fidelity, and penetration.

Cost (n=10)

It is similarly insufficient that the project is considered successful if it is “cost-effective” or a low-cost option, although ten of the sixteen (62.5%) interventions address cost of their interventions (Borde, 2016; Brunson, Busenitz, Sabatini, & Spicer, 2013; Clark, Pinedo, Fadus, & Capuzzi, 2012; Khatri, Iddings, Overmars, Hasan, & Gerber, 2011; Mangoua-Allali, Coulibaly, Ouattara, & Gourene, 2012; Ncube & Pawandiwa, 2013; Ngai & Fenner, 2014; Ojomo, Elliott, Goodyear, Forson, & Bartram, 2015; Penning de Vries, 2007; Peter & Nkambule, 2012).

While a majority of the search results evaluated cost, they did so by using a rudimentary understanding of this outcome. Typical evaluations consider only whether the intervention is cheap to implement, initiate usage or replace if necessary. Implementation cost, however, considers multiple aspects of pricing, cost and financing, including from the perspective of users, implementing organizations and sustaining partners.

Feasibility (n=10)

Feasibility assesses whether an intervention and community are jointly considered in terms of whether the intervention can be implemented as designed, and in water systems, this relates to the capacity of the users, community, or implementing agency to collaborate with and support end users of the technology or system over time.

Fidelity (n=8)

Fidelity, perhaps one of the most critical outcomes, addresses the extent to which an intervention is implemented in adherence with its original design. Fidelity is the intervention being implemented as planned or tested in pilot studies. Adaptation, as described by Durlak & DuPre (2008), is the counterpart to fidelity, as adaptation reflects the intervention being implemented based on the best 'fit' for the target community. Fidelity and adaptation have an inverse relationship to one another, as the adaptation increases the fit and possibly the acceptance or adoption while decreasing the fidelity. Only 50% of search results discussed fidelity of intervention usage once implemented or planned adaptation.

Penetration (n=4)

Penetration, or the extent to which the intervention reaches a significant number of people, has already translated this into water system terms through Sustainable Development Goal 6.1.1: "Proportion of population using safely managed drinking water services" (United Nations, n.d.). This implementation outcome could indicate that additional users beyond the initial intervention group are using the technology or system, whether due to the purposeful expansion of the intervention or uptake from word of mouth. Not surprisingly, the four articles that include this implementation outcome are the subset of those with all eight outcomes and described earlier.

Sustainability (n=0)

Sustainability, the final implementation outcome, is then a natural product of the achievement of the preceding seven outcomes. Sustainability is the systematic integration and sustained usage of an intervention, and the components that facilitate this sustained usage. These might refer to the existence of resources within or nearby the community to source parts and labor for maintenance of the water system, the funding to procure such resources, and the length of time beyond the initial implementation that individuals continue to use the filters or water system. It can also include whether a governing body is successfully maintaining operation of the system, including successfully transitioning leadership of the body when necessary.

While nearly every study emphasized a desire to achieve sustainability, none (n=0) discussed institutionalized usage, established a timeframe for sustainability, nor provided evidence for sustained usage over time. Instead, researchers typically provided conjecture as to whether their interventions would achieve sustainability.

Insights

A few trends emerged in reviewing these studies. Studies that paid considerably more attention to the areas of feasibility, fidelity, and penetration were able to better demonstrate that the continued maintenance and use of a new drinking water system are influenced by these implementation outcomes (Borde, 2016; Brunson, Busenitz, Sabatini, & Spicer, 2013; Ncube & Pawandiwa, 2013; Ngai & Fenner, 2014). For example, Ngai and Fenner created a detailed causal loop diagram to illuminate the impact of cost, acceptability, and penetration of biosand filters in India on sustained and expanded future use of the filters in a community (2014). Borde also explores barriers to adoption and penetration, challenges of fidelity, and cost realities in using Solar Energy Disinfection of Water (SODIS) in multiple countries and emergency settings (2016). Brunson et al., meanwhile, evaluated multiple technologies, including boreholes, household water chlorination, the use of bone char, and water filtration in settings throughout Africa and South America. They found numerous reasons for discontinued use, including lack of access to a supply chain for maintenance, and reasons for continued use, like provision of safe water storage containers (2013). Comprehensive evaluations such as these are instrumental in providing practitioners and researchers with valuable information on the relationships between implementation outcomes.

Several studies also conducted evaluations that included multiple countries (Barnes, Ashbolt, Roser, & Brown, 2014; Borde, 2016; Brunson, Busenitz, Sabatini, & Spicer, 2013; Ojomo, Elliott, Goodyear, Forson, & Bartram, 2015; Penning de Vries, 2007) or multiple interventions (Barnes, Ashbolt, Roser, & Brown, 2014; Brunson, Busenitz, Sabatini, & Spicer, 2013; Peter & Nkambule, 2012), including two – Barnes, et al (2014) and Brunson, et al (2013) – that evaluated interventions across multiple countries and multiple interventions. These findings may signal a desire to see drinking water interventions in a systematic way, and to find commonalities that may result in strategies successful across geography and technology. It also signals which outcomes are currently of greatest interest to researchers. For example, adoption is clearly a priority, as shown by the nearly 40% of studies that evaluated interventions across multiple countries and nearly one quarter that evaluated multiple types of interventions (Barnes, Ashbolt, Roser, & Brown, 2014; Borde, 2016; Brunson, Busenitz, Sabatini, & Spicer, 2013; Casanova, Walters, Naghawatte, & Sobsey, 2012; Clark, Pinedo, Fadus, & Capuzzi, 2012; Holm, 2012; Mangoua-Allali, Coulibaly, Ouattara, & Gourene, 2012; Ncube & Pawandiwa, 2013; Ngai & Fenner, 2014; Ojomo, Elliott, Goodyear, Forson, & Bartram, 2015; Penning de Vries, 2007; Peter & Nkambule, 2012; Raghavan, Chockalingam, & Johar, 2013; Suhardiman, Clement, & Bharati, 2015). In the absence of a systematic understanding of implementation outcomes, it appears researchers are looking for commonalities in an effort to design effective strategies across geography and technology, thus indicating IS methodologies would likely be welcome in this field.

There is a clearly significant emphasis on the initial implementation outcomes (acceptability, appropriateness, adoption), likely because they reflect day-to-day program implementation measures. However, the true success is in sustainability, and yet none of the studies evaluated sustained usage over time nor systematic integration of interventions into communities. In part, this is due to premature evaluation of programs immediately following implementation, which does not allow an intervention to take hold in a user base over time and be evaluated at some further point in time. It is imperative that we measure the interaction between outcomes. WaSH researchers, particularly those seeking to improve drinking water systems, are clearly concerned about implementation and the dynamic interplay between various elements of the process to plan, execute and maintain these solutions. These relationships can only be uncovered through the use of IS which gives us a framework through which we can ask powerful questions that will help systematically address implementation issues.

While there is some overlap among the results in this literature review, most articles attempt to provide a unique or distinct approach when implementing these interventions in rural settings in LMIC. Some evaluations of single interventions have suggested “must-haves” (Holm, 2012) and these will no doubt greatly improve the implementation of these individual water filtration technologies and systems. But to achieve sustainability at scale across a variety of interventions, we must begin to take a more systematic approach. The influence and impact of implementation outcomes on each other remain anecdotal and has not been studied using implementation science research methods. It may be, for instance, that the degree to which a community takes ownership of a water system and adopts it as a primary method for delivering clean water is, in fact, superior to other outcomes. While some researchers describe implementation outcomes, none have developed explicit theories of how these outcomes interact with each other. These individual and collective contributions to sustainability are of critical import to quality implementation, and we must now develop new ways of measuring and defining these issues of implementation to achieve that goal. The systematic measurement afforded by implementation science is the kind of information that we do need but requires significant further research in this critical area of sustainable development.

Proposed Research Agenda

Some salient suggestions can be gleaned from the original implementation science research agenda presented in Durlak and DuPre (2008). First, the WaSH sector must agree upon definitions and indicators for each implementation outcome as it pertains to drinking water delivery systems, because “Science cannot study what it cannot measure accurately and cannot measure what it cannot define” (Durlak & DuPre, p.342). These should then be integrated into the JMP to collect data systematically and over time, as Fixsen suggests (Fixsen, Naoom, Blase, & Friedman, 2005).

As shown by the fact that none of the studies evaluated sustainability, in large part due to the timing of the evaluation and proximity to earlier implementation phases, interventions should be given significantly more time to unfold before being evaluated so as to understand the full breadth of the implementation process better. As seen in the results presented in this paper, evaluating a drinking water system after a handful of months from the initial implementation only serves to understand whether initial adoption and acceptability exist. This approach rarely captures whether the intervention penetrated further into a community, whether it remained acceptable and was adopted over time, and it presumes sustainability based on initial usage without returning to evaluate sustained use over a more prolonged time period. Most of all, this truncated timeframe does not allow for a deep understanding of the relationships between different implementation outcomes. Researchers should wait to evaluate an intervention until it has had one to three years of implementation, as suggested by Fixsen et al. (2005) and Felner et al. (2001), to evolve. Each component of an intervention should also be separately considered regarding its implementation outcomes. For example, if user satisfaction is high, but system maintenance is failing, we should not “throw the baby out with the bath water.” Rather, we should carefully consider and evaluate the implementation of each aspect. Durlak & DuPre also recommend analyzing implementation outcomes for different populations, which is also applicable to WaSH interventions (2008). This recommendation means evaluating adoption within subgroups of a community, or evaluating how an intervention achieves implementation outcomes when translated into a different community, region or country than its pilot group.

Similarly, Durlak & DuPre (2005) recommend intervention be considered within their cultural context so as to be successfully and appropriately adapted. These adaptations need to be researched well, too, to understand whether they are “surface” or “deep structure” adaptations (Resnicow, Baranowski, Ahluwalia, & Braithwaite, 1999). Durlak & DuPre draw a distinction between these two levels, describing surface adaptation as “decisions regarding how messages or materials are changed to match the observable characteristics of a population” but that do not alter the fundamental principles of the intervention. Deep structure adaptation, meanwhile, includes “pivotal cultural, social, environmental, or psychological factors specific to a group, and incorporating these elements into the intervention is more likely to involve an intervention’s core components” (2005). A minority of the studies reviewed in this paper discussed adaptations made in light of the sociocultural context, language or other characteristics of the cultural environment and population, demonstrating that additional research is required.

Recommendations for Public Health Leadership

The core functions of public health leadership play a critical role in integrating IS into drinking water system implementation. Evaluation, assurance, equity, effectiveness (Aday, 2004) will undoubtedly be improved if these interventions are more successful and sustainable. Ministers of health, nongovernmental organization leaders, and technical experts from donor countries must now channel the resources from the latest, hottest innovation to substantive consideration, research and investigation into the multi-layered context in which they are implementing a clean water delivery system.

Academia can provide leadership in this space through implementation research that contributes to the body of knowledge on successful implementation strategies, common determinants, and useful frameworks. Journal editors can also contribute to this knowledge gap by enacting more stringent requirements for submitting authors to present more rigorous evaluation of project implementation. Researchers must analyze not just “whether” an intervention was successfully implemented, but “how,” “why,” and the relationship between implementation outcomes. By providing this kind of process analysis and by taking a more systematic view of their individual interventions, researchers can enable future implementers to build upon what has already been learned and to continue building the base of evidence.

Leadership, however, is not simply about designing and delivering programs or determining where dollars are spent. Effective leadership also comes from personal growth and change by those with the power to make decisions and those who have influence with decision makers. Insightful questions to ask would be, what do we assume about a community that leads us to implement unsustainable interventions (e.g., children in LMICs have an abundance of playtime)? What implicit yet unspoken facts are thought to be true about individuals, local leadership, or the surrounding infrastructure and support system? The application of implementation science into public health solutions as well as implementation outcome research such as that as outlined in this paper can assist leaders in uncovering biases and fallacies are held both at the personal and industry level.

Ultimately, the most meaningful form public health leadership will take in this space is the radical paradigm shift from seeking quick solutions to systems thinking, user-centered design and a comprehensive understanding of how we can achieve outcomes that are truly sustainable.

Limitations

There are several limitations of this paper. As the field of implementation science is still relatively new in global health and it is not well understood among practitioners, reviewing the literature for whether implementation outcomes have been evaluated in an intervention is challenging. Terms to describe fidelity and adoption may not be used specifically even though the concepts are in play. This inconsistent use of terminology significantly reduces the feasibility of conducting a complete and thorough search of all peer-reviewed literature since 2000 using all possible terms; it is nearly impossible to ensure with 100% certainty that the studies found are the only ones in which implementation outcomes are addressed. However, to gain a relatively comprehensive view of whether the importance of implementation has begun emerging into the field, it is assumed that an author would make overt reference to implementation in the title, abstract or keywords. Thus, while this may limit the literature review, it does so purposefully and productively, to determine at what level we have begun using the IS approach in this sector.

Conclusion

As this review shows, sustainability, as defined by sustained use of an intervention over time, has become something hoped for or assumed based on how the project began and would likely continue. Sustainability, however, has neither the qualities of magic nor an unknowable formula. Through purposeful and systematic research, we can discover what makes interventions like clean water filtration and piping systems better integrated into communities, more widely adopted, and used continuously for years after initial implementation. With rigorous outcome data and through the actions and processes that guide the intervention's implementation, global health practitioners can improve the sustainability of proven interventions. Other social service sectors have demonstrated the links between quality implementation and achieving implementation outcomes, and implementation science already has the tools that will support quality implementation of these interventions. It is time we began to use them to ensure access to clean water for all.

References

Aarons, G. A., Hurlburt, M., & Horwitz, S. M. (2011). Advancing a conceptual model of evidence-based practice implementation in public service sectors. *Administration and Policy in Mental Health and Mental Health Services Research*, 38(1), 4–23.

Aday, L. A. (2004). Evaluating the healthcare system: effectiveness, efficiency, and equity (3rd ed.). Chicago, Ill.: Academy Health.

Amjad, U., Ojomo, E., Downs, K., Cronk, R., & Bartram, J. (2015). Rethinking Sustainability, Scaling Up, and Enabling Environment: A Framework for Their Implementation in Drinking Water Supply. *Water*, 7(4), 1497–1514.

Barnes, R., Ashbolt, N., Roser, D., & Brown, P. (2014). Implementing sustainable water and sanitation projects in rural, developing communities. *Waterlines*, *33*(1), 71–88.

Borde, P. (2016). Community challenges when using large plastic bottles for Solar Energy Disinfection of Water (SODIS). *BMC Public Health*, *16*(1).

Brunson, L. R., Busenitz, L. W., Sabatini, D. A., & Spicer, P. 2013. In pursuit of sustainable water solutions in emerging regions. *Journal of Water Sanitation and Hygiene for Development*, 34, 489–499.

Campana, M. (2010, June 30). Have PlayPumps Played Out? [Blog]. Retrieved March 31, 2017, from http://www.waterwired.org/2010/06/have-playpumps-played-out.html.

Casanova, L. M., Walters, A., Naghawatte, A., & Sobsey, M. D. 2012. A post-implementation evaluation of ceramic water filters distributed to tsunami-affected communities in Sri Lanka. *Journal of Water and Health*, 102, 209–220.

Clark, P. A., Pinedo, C. A., Fadus, M., & Capuzzi, S. 2012. Slow-sand water filter: Design, implementation, accessibility and sustainability in developing countries. *Medical Science Monitor*, 187, RA105-RA117.

Durlak, J. A., & DuPre, E. P. (2008). Implementation matters: A review of research on the influence of implementation on program outcomes and the factors affecting implementation. *American Journal of Community Psychology*, 41(3-4), 327.

Felner, R. D., Favazza, A., Shim, M., Brand, S., Gu, K., & Noonan, N. (2001). Whole school improvement and restructuring as prevention and promotion: Lessons from STEP and the Project on High Performance Learning Communities. *Journal of School Psychology*, 39(2), 177–202.

Fixsen, D., Naoom, S., Blase, K., Friedman, R., Wallace, F. (2005). *Implementation Research: A Synthesis of the Literature*. Tampa, FL: University of South Florida, Louis de la Parte Florida Mental Health Institute, National Implementation Research Network.

Foster, T. (2013). Predictors of Sustainability for Community-Managed Handpumps in Sub-Saharan Africa: Evidence from Liberia, Sierra Leone, and Uganda. *Environmental Science & Technology*, 47(21), 12037–12046.

FRONTLINE/World. Interview with Amy Costello. Public Broadcasting Service. 2010. Retrieved March 31, 2017, from http://www.pbs.org/frontlineworld/stories/southernafrica904/reporter.html.

Gallego-Ayala, J., & Juízo, D. 2011. Strategic implementation of integrated water resources management in Mozambique: An A'WOT analysis. *Physics and Chemistry of the Earth*, 3614–15, 1103–1111.

Holm, R. H. 2012. Recent History Provides Sustainable African Water Quality Project Insight. *Ground Water*, 505, 808–811.

Khatri, K., Iddings, S., Overmars, M., Hasan, T., & Gerber, F. (2011). Implementation of drinking water safety plans and lessons from the Pacific islands. *Waterlines*, *30*(3), 235–247.

Krause, J., Van Lieshout, J., Klomp, R., Huntink, E., Aakhus, E., Flottorp, S., … others. (2014). Identifying determinants of care for tailoring implementation in chronic diseases: an evaluation of different methods. *Implementation Science*, *9*(1), 102.

Khurana, I., & Sen, R. (2008). *Drinking water quality in rural India: Issues and approaches* (Background Paper). WaterAid India.

Luoto, J., Shekelle, P. G. b, Maglione, M. A., Johnsen, B., & Perry, T. 2014. Reporting of context and implementation in studies of global health interventions: A pilot study. *Implementation Science*, 91.

Mangoua-Allali, A. L. C., Coulibaly, L., Ouattara, J. M. P., & Gourene, G. (2012). Implementation of biosand filters in rural area for drinking water production. *African Journal of Food Science*, *6*(24), 574–582.

Murray, C. J., Lopez, A. D., & others. (1996). *Global burden of disease (Vol. 1)*. Boston: Harvard University Press.

National Institute of Health, Fogarty International Center. (n.d.). https://www.fic.nih.gov/researchtopics/pages/implementationscience.aspx

Ncube, M., & Pawandiwa, M. N. (2013). Water safety planning and implementation: lessons from South Africa. *Journal of Water, Sanitation and Hygiene for Development*, *3*(4), 557–563.

Ngai, T. K. K., & Fenner, R. A. 2014. Designing programme implementation strategies to increase the adoption and use of biosand water filters in rural India. *Water Alternatives*, 72, 320–341.

Nilsen, P. (2015). Making sense of implementation theories, models and frameworks. *Implementation Science*, 10, 53.

Nino, F. S. (n.d.). Water and Sanitation. Retrieved from http://www.un.org/sustainabledevelopment/water-and-sanitation/

Obiols, A., & Erpf, K. (2008). Mission Report on the Evaluation of the PlayPumps Installed in Mozambique. Swiss Resource Centre and Consultancies for Development, St Gallen.

Ojomo, E., Elliott, M. b, Goodyear, L., Forson, M., & Bartram, J. 2015. Sustainability and scale-up of household water treatment and safe storage practices: Enablers and barriers to effective implementation. *International Journal of Hygiene and Environmental Health*, 2188, 704–713.

Penning de Vries, F. 2007. Learning Alliances for the broad implementation of an integrated approach to multiple sources, multiple uses and multiple users of water. *Water Resources Management*, 211, 79–95.

Peter, G., & Nkambule, S. E. 2012. Factors affecting sustainability of rural water schemes in Swaziland. *Physics and Chemistry of the Earth*, 50–52, 196–204.

Proctor, E. K., Silmere, H., Raghavan, R., Hovmand, P., Aarons, G., Bunger, A., … Hensley, M. (2011). Outcomes for Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda. *Administration and Policy in Mental Health and Mental Health Services Research*, 38(2), 65–76.

Proctor, E. K., Powell, B. J., & McMillen, J. C. (2013). Implementation strategies: recommendations for specifying and reporting. Implementation Science, 8(1), 139.

Raghavan, R., Chockalingam, R., & Johar, Z. (2013). Implementing public health interventions in developing countries: a transdisciplinary solution for safe drinking water in rural India. *Transdisciplinary Public Health: Research, Education, and Practice.* San Francisco, CA: Jossey-Bass, 297-317.

Resnicow, K., Baranowski, T., Ahluwalia, J., & Braithwaite, R. (1999). Cultural sensitivity in public health: defined and demystified. *Ethnicity & Disease*, 9(1), 10–21.

Rosen, A., & Proctor, E. K. (1981). Distinctions between treatment outcomes and their implications for treatment evaluation. *Journal of Consulting and Clinical Psychology*, 49(3), 418–425.

Suhardiman, D., Clement, F., & Bharati, L. 2015. Integrated water resources management in Nepal: key stakeholders' perceptions and lessons learned. *International Journal of Water Resources Development*, 312, 284–300.

Therkildsen, O. (1988). Watering white elephants? Lessons from donor funded planning and implementation of rural water supplies in Tanzania. Uppsala, Sweden: Scandinavian Institute of African Studies.

Tobler, N. S. (1986). Meta-analysis of 143 adolescent drug prevention programs: Quantitative outcome results of program participants compared to a control or comparison group. *Journal of Drug Issues*, 16(4), 537–567.

United Nations. (n.d.). Goal 6: Ensure access to water and sanitation for all. Retrieved March 2, 2017, from http://www.un.org/sustainabledevelopment/water-and-sanitation/.

United Nations. (2014). International Decade for Action "Water for Life" 2005-2015. Focus Areas: The human right to water and sanitation. Retrieved March 31, 2017, from http://www.un.org/waterforlifedecade/human_right_to_water.shtml.

Wandersman, A., Duffy, J., Flaspohler, P., Noonan, R., Lubell, K., Stillman, L., … Saul, J. (2008). Bridging the Gap Between Prevention Research and Practice: The Interactive Systems Framework for Dissemination and Implementation. *American Journal of Community Psychology*, 41(3–4), 171–181.

WHO / UNICEF Joint Monitoring Programme: mission & objectives. (n.d.). Retrieved March 31, 2017, from https://www.wssinfo.org/about-the-jmp/mission-objectives/.

World Health Organization. (n.d.). MDG 7: ensure environmental sustainability. Retrieved March 31, 2017, from http://www.who.int/topics/millennium_development_goals/mdg7/en/.

World Health Organization & UNICEF. (2015). Progress on sanitation and drinking water–2015 update and MDG assessment. World Health Organization.

World Intellectual Property Organization. (n.d.). When Innovation is Child's Play. Retrieved March 31, 2017, from http://www.wipo.int/ipadvantage/en/details.jsp?id=2603.

Zenios, S., Denend, L., & Sheen, E. (2012). PlayPumps International: Gaining User Buy-In. *Global Health Innovation Insights.* Stanford.