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The Applications of Implementation Science in Water, Sanitation, and Hygiene (WASH) Research and Practice

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Background: Delivery of high quality, at-scale, and sustained services is a major challenge in the water, sanitation, and hygiene (WASH) sector, made more challenging by a dearth of evidence-based models for adaption across contexts in low- and middle-income countries.

Objective: We aim to describe the value of implementation science (IS) for the WASH sector and provide recommendations for its application.

Methods: We review concepts from the growing field of IS—defined as the "scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and hence, to improve the quality and effectiveness of health services"—and we translate their relevance to WASH research, learning, and delivery.

Discussion: IS provides a suite of methods and theories to systematically develop, evaluate, and scale evidence-based interventions. Though IS thinking has been applied most notably in health services delivery in high-income countries, there have been applications in low-income settings in fields such as HIV/AIDS and nutrition. Expanding the application of IS to environmental health, specifically WASH interventions, would respond to the complexity of sustainable service delivery. WASH researchers may want to consider applying IS guidelines to their work, including adapting pragmatic research models, using established IS frameworks, and cocreating knowledge with local stakeholders. https://doi.org/10.1289/EHP7762

Introduction

The water, sanitation, and hygiene (WASH) sector has struggled to achieve at-scale and sustained improvements to its services, particularly for the world's most vulnerable populations (WHO/UNICEF 2019). Inconsistent and nonfunctional water supply and underused and deteriorating toilets undermine significant progress toward achieving universal access to safe water and sanitation. The United Nations (UN) estimates that at least 29% of the global population relies on some level of fecal or chemically contaminated or unimproved water source for drinking (WHO/UNICEF 2019). Two billion people do not use sanitation facilities coupled with safe excreta disposal and treatment services, and 3 billion people lack handwashing facilities with available soap and water (WHO/UNICEF 2019). Despite the strong biological plausibility that improving WASH conditions is a basic strategy for yielding gains in health, several rigorous, high-profile field trials reveal minimal or no reductions in childhood diarrheal disease or undernutrition from WASH interventions typically delivered to rural populations in low- and middle-income countries (LMICs) (Clasen et al. 2014; Humphrey et al. 2019; Luby et al. 2018; Null et al. 2018; Patil et al. 2014; Pickering et al. 2015). The evidence for health impact from WASH service delivery in urban areas in LMICs is also limited (Barreto et al. 2007).

The failure to sustain services and reliably quantify health gains in the sector is perhaps rooted in the complexity of innovation and implementation strategy requirements, limited external validity, diverse objectives, and the multiple service providers and multilevel nature of WASH interventions. Simply stated, there is limited rigorous research on what works to achieve sustained coverage and use at scale across myriad contexts. Organizational and behavioral theories are rarely applied to designing and adapting interventions, and context and delivery are seldom described thoroughly to inform scale-up and replication. In some cases, promising WASH innovations have been rapidly scaled with little rigorous assessment of how barriers and facilitators of favorable implementation outcomes vary across local settings (Hueso and Bell 2013; Sinharoy et al. 2017).

The challenges of sustaining WASH provision at scale, and for these gains to translate to health gains, warrant a new paradigm for how the sector operates and learns, especially as the sector aims to meet sustainable development goal six (SDG-6) to provide universal access to "safely managed" water and sanitation and "basic" hygiene by 2030 (WHO/UNICEF 2019). The SDG-6 targets aspire for higher quality WASH services that are more closely aligned with improved health and well-being outcomes than predecessor global goals. Achieving these targets will require complex and transformative interventions that reach consistently neglected populations and create institutional capacity able to monitor and maintain standards of quality and use of services (Pickering et al. 2019).

We believe that the field of implementation science (IS) offers theory, process, and rigor for the WASH sector to better deliver and evaluate its investments and disseminate its findings. IS focuses on the translation gap between what is learned in the laboratory or within efficacy studies and what is delivered under real-world conditions (Theobald et al. 2018). Community and stakeholder engagement are key to IS to ensure relevant questions and direct application. IS objectives have been applied to improve the delivery of global health programs (Madon et al. 2007; Van Belle et al. 2017), including in the HIV/AIDS (Hickey et al. 2017), nutrition (Tumilowicz et al. 2019), and health systems sectors (Remme et al. 2010; Sanders and Haines 2006). However, there have been limited attempts to apply IS to the WASH context (Setty et al. 2019) or to environmental health interventions in general (Rosenthal et al. 2017; 2020). Here, we describe the broader objectives of IS, defining fundamental terminology and concepts. Next, we identify the key challenges of operationalizing and delivering WASH interventions. We then discuss common IS guidelines that WASH researchers may want to consider applying to their work, including adapting pragmatic research models, using established IS frameworks, and cocreating knowledge with local stakeholders.

General Implementation Science Objectives and Concepts

In its earliest applications, IS was focused on improving health care practice in high-income countries. The most traditional

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definition of the field is the "scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and hence, to improve the quality and effectiveness of health services" (Eccles and Mittman 2006). However, as the field has grown outside clinical settings, sectors have made adaptations and additions to its scope. A common criticism is that the literature has competing nomenclature and frameworks (Nilsen 2015). For simplicity, we consistently use the term "implementation science" throughout this commentary. We recognize that some of the ideas we cite come from several alias or ally fields, including implementation research, translational science research, dissemination research, comparative effectiveness research, and others (Glasgow et al. 2012; Peters et al. 2013; Woolf 2008).

IS aims to apply evidence-based health interventions in high-risk populations with "greater speed, efficiency, appropriate fidelity, and relevant coverage" (Kemp et al. 2018). The defining qualities of IS in global health are its flexibility, real-world focus, emphasis on processes and outcomes for intervention delivery, application across stakeholders, and fit-to-purpose methods. These qualities are critical for global health research to reduce health disparities, inform policy design and implementation, improve management, enhance service delivery, and empower communities (Theobald et al. 2018). Those researchers focusing on improving WASH evidence and evidence-based practice may already incorporate these qualities into their work and examine implementation challenges. The past several years have also seen a greater focus on implementation research from some key donors (USAID 2020). However, a traditional gap persists between sector research focused on technology development and health impact assessment and programmatically relevant operational learning focused on coverage and delivery. Implementation research in WASH has often focused on institutional knowledge within organizations and has been ad hoc, without applying systematic methods. The purpose of this commentary is to highlight IS concepts and practices that the WASH sector as a whole can adapt.

A key framework by Proctor et al. (2009; Figure 1) depicts the basic concepts and domains of study within IS. A significant feature of the framework is that it disaggregates the intervention by its innovation or technology and implementation strategy. We note that the WASH innovations frequently employed—toilets, taps, soap, behavior change communication, etc.—are conventionally thought of as interventions, when in fact they are technologies that must be coupled with evidence-based implementation strategies. Examples of WASH innovations fall somewhere under categories of programs [ongoing service models or campaigns—e.g., community hygiene clubs, village water and sanitation committees, Community-Led Total Sanitation (CLTS)], products (WASH hardware and infrastructure), practices (WASH behaviors), principles (established and emerging theories—e.g., sanitation coverage thresholds, economies of scale), and policies (e.g., subsidies, standards, targeting) (Brown et al. 2017). Their counterpart, implementation strategies, are the intentional methods used to improve the adoption, delivery, and sustainability of the innovation (Proctor et al. 2013). Strategies are broadly grouped by six processes: planning (identifying actors, actions, targets, temporality, and dose), educating (promoting innovation and gaining buy-in), financing (funding, incentive structures), restructuring (reforming roles, systems adaptation), quality management (monitoring, maintenance, feedback), and attending to policy context (laws, enforcement, and institutions) (Powell et al. 2012; Proctor et al. 2013). For example, a sanitation program targeting slums as an intervention alone will likely be unsustainable without processes that restructure the roles of utilities and small and informal service providers and the policy context that enables enforcement of standards in those communities (Haque et al. 2020; Trémolet and Halpern 2006). Powell et al. (2015) compile

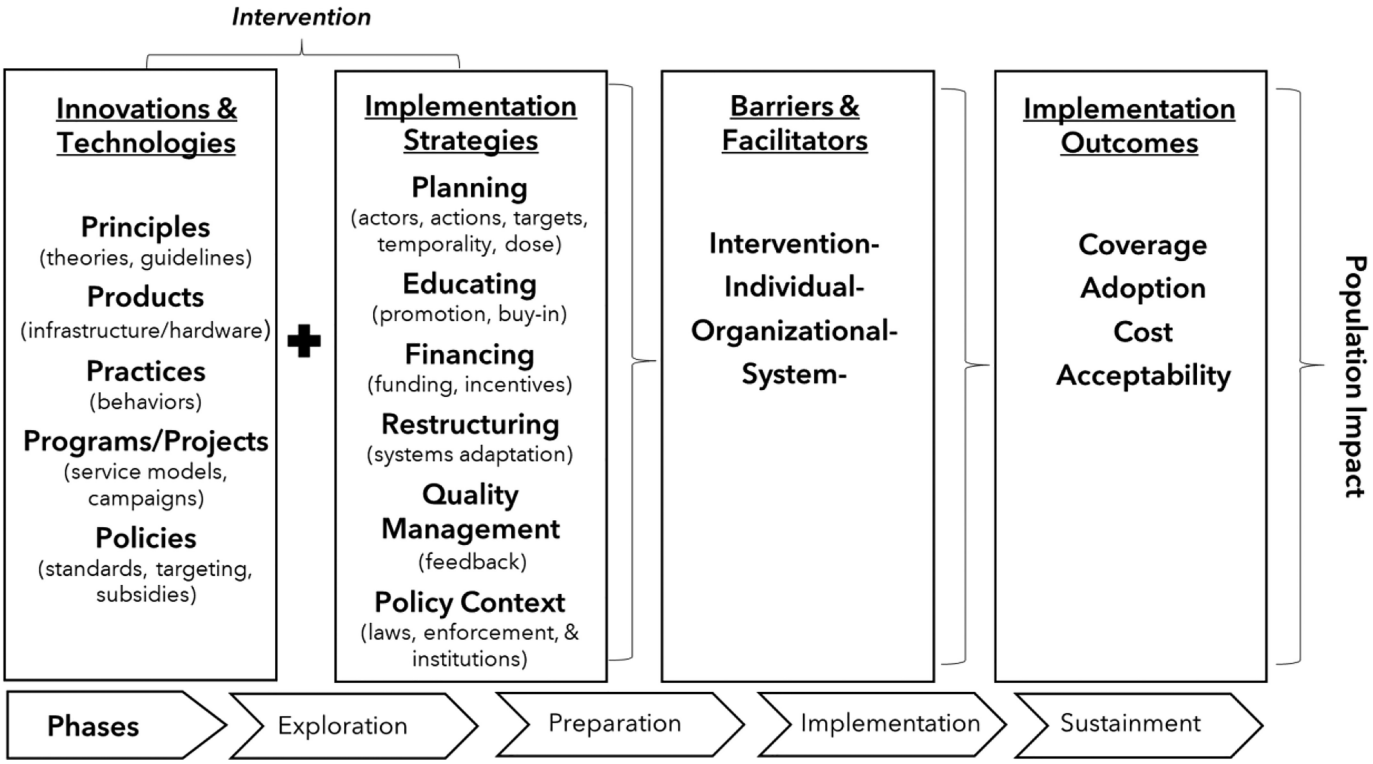

Figure 1. Conceptual framework for Implementation Science research (figure adapted from Proctor et al. 2009 and builds on concepts from Brown et al. 2017; Powell et al. 2012; Powell et al. 2020).

and define more than 70 discrete implementation strategies that illustrate the range of activities used to build a multifaceted approach. The intervention additionally faces contextual barriers and facilitators embedded at multiple levels (e.g., intervention-, individual-, organizational-, and system- levels) during real-world implementation. These factors will influence implementation outcomes, which measure the degree to which the intervention was delivered as intended (Fixsen et al. 2005; Proctor et al. 2013). An intervention will fail to deliver impacts due to implementation failure, theory failure, or both (Suchman 1968). Implementation failure results from poor implementation outcomes. Theory failure occurs when the intervention was implemented correctly but failed to achieve desired impact due to a problem in the underlying theory of change, an understanding of how the intervention should catalyze change.

Research on WASH provision has largely stayed in the exploration phase of this framework, studying questions on innovations' ability to deliver health gains without sufficient attention to the necessary pathway for health impact in a given context. The biological plausibility that safe or improved WASH is a foundation of public health is well established in history (Wagner and Lanoix 1958; Cutler and Miller 2005; Tulchinsky 2018). Yet, recent field trials have raised concerns that common WASH interventions implemented in LMICs are not delivering anticipated health gains, even under relatively controlled conditions (Clasen et al. 2014; Humphrey et al. 2019; Luby et al. 2018; Null et al. 2018; Patil et al. 2014; Pickering et al. 2015). To conclude from these trials that WASH, in principle, does not improve health, fails to consider the contextual and implementation nuances surrounding the tested interventions in each setting (Cumming et al. 2019; Whittington et al. 2020). Possible explanations for limited health impact have largely focused on the inability to effect implementation outcomes related to coverage and adoption, including the failure to break relevant pathways of fecal exposure, inadequate behavior change, and insufficient coverage to surpass sanitation thresholds that would improve health (Cumming et al. 2019; Pickering et al. 2019).

Challenges of WASH Provision

The interpretation of recent trials and faltering global progress in WASH delivery illustrate the complexity of providing sustainable WASH interventions at scale. We summarize this complexity by outlining four key challenges of WASH provision: *a*) complex innovation and implementation requirements; *b*) limited external validity of interventions; *c*) inconsistent development sector objectives; and *d*) diverse service providers working at multiple levels. Taken together, these four challenges demonstrate the demand for rigorous IS research on the development and delivery of evidence-based interventions, how interventions respond to different contexts, and the implementation outcomes that lead to population health and social impact.

Complex innovation and implementation requirements. We assert that WASH innovations and their implementation strategies are multifaceted, expensive, and not well-defined in the sector. Disrupting multiple exposure pathways to diverse enteric pathogens (Platts-Mills et al. 2015) entails a well-managed system of WASH interventions, with no single technology or behavior likely being sufficient to accrue significant health or social benefit and no single implementation strategy being able to achieve sufficient coverage and uptake of WASH innovations. The findings of recent trials have sparked debate on the utility of simple and fragmented WASH interventions in LMICs and the need for "transformative WASH" that requires investment in large-scale water and sanitation systems that enable behavior change (Cumming et al. 2019; Pickering et al. 2015). However, we lack an understanding of the technology and processes needed for this transformation. Although the sector has limited evidence on effective methods that lead to improved coverage and use of innovations over time, there have been successes in equitable improvements to sanitation, provision of continuous water supply, and programs to increase handwashing and hygiene behaviors (Biran et al. 2014; Kirby et al. 2019). In many of these cases, documentation of that delivery process has been limited. Process questions about the required intensity of behavior-change promotion, appropriate financing mechanisms, structuring service-provider roles and incentives, and improving monitoring and information systems are often left unanswered.

Limited external validity of interventions. A WASH intervention proven to be effective in one setting is not guaranteed to be effective in another. Dominant pathways of fecal exposure and pathogens are dynamic and differ by temporal and spatial scales (Kotloff et al. 2013; Robb et al. 2017; Sclar et al. 2016) due to a multitude of factors, such as community-level sanitation, climate, animal management, hydrogeology, vaccine coverage, social norms, etc. (Ercumen et al. 2017; Penakalapati et al. 2017). Broken water taps and pumps are also attributable to contextual factors, such as managing and incentive structures, hydrogeology, and access to energy (Alexander et al. 2015; van den Broek and Brown 2015; Whaley and Cleaver 2017; Yerian et al. 2014). So, too, a behavioral approach targeting specific drivers or norms in one context cannot readily be transferred to another context.

Generalizability concerns are evident in sanitation behavior-change programs that are shown to lose their effectiveness when replicated in new contexts. The initial deployment of CLTS, for example, was deemed promising in Bangladesh for eradicating open defecation behavior (Kar and Chambers 2008); however, CLTS exhibits varying success as an export to other countries. Ethiopia, for instance, had initial achievements with CLTS, with significant reduction of open-defecation rates between 2000 and 2015, decreasing from 80% to 27% (WHO/UNICEF 2017). However, Ethiopia faces problems of "slippage," where household members revert to open-defecation behavior or the community returns to having a high prevalence of sanitation-related diseases post program (Abebe and Tucho 2020). Slippage problems after CLTS deployment are being commonly reported in monitoring surveys throughout countries (Crocker et al. 2017; Harter and Mosler 2018; Jerneck et al. 2016). Different forms of CLTS have now spread to nearly 60 countries, but little of its diffusion is guided by robust scientific evidence (Zuin et al. 2019). Increasing implementation research finds that the innovation's effectiveness in sustaining villages that cease open defecation depends on a variety of household, community, policy environment, and program implementation factors, such as financial resources, access to construction materials, social cohesion, and strong local leadership (Venkataramanan et al. 2018; Zuin et al. 2019). A WASH intervention needs to be carefully tailored to its environmental, social, and political contexts, yet there is scant research on contextual factors that enable effective implementation (Dreibelbis et al. 2013; Whittington et al. 2020).

Inconsistent development sector objectives. The sector has a diverse constituency of interests, which we find results in a tension to determine whether the end goal of WASH investments should be, for example, health impact or the sustainable provision of services itself. WASH was declared a human right in 2010 as part of UN Resolution 64/292 (2010), but health, food security and nutrition, and gender equity are also major drivers of sector investment (HLPW 2016). Efforts to provide safe, reliable, and sufficient quantities of water and to provide for the effective separation of feces are largely implemented outside of the health system (Trémolet and Rama 2012), despite clear health end points.

WASH services delivered by state actors (e.g., the Ministry of Water, utilities), informal actors, or nongovernmental organizations (NGOs) may lack explicit health objectives, either operating within a financial model of service delivery or using a rights-based lens (Satterthwaite 2014; Sweetman and Medland 2017). WASH is typically seen as an input for meeting objectives of multiple sectors, scattering opportunities for improving WASH across development investments (Trémolet and Rama 2012; Seppälä 2002). Simple provision of SDG-6-defined technologies alone cannot guarantee knock-on effects toward achieving multiple development goals (Wolf et al. 2018). We note that a lack of consistent objectives makes it difficult to define systematic measures of success and thus develop theory-driven interventions and monitoring and accountability structures.

Diverse service providers working at multiple levels. A final challenge is that the sector operates as a complex system, with multiple levels of diverse service providers such as governments and nonstate actors, including NGOs, the private sector, and communities. Though there are a number of guidelines and standards for service provision available at national levels, the variety of vertical and horizontal actors involved in service delivery makes it difficult to assign and enforce liability (Seppälä 2002). Services become decentralized in practice, with a number of nonstate actors ultimately having discretion over how a WASH program is defined and delivered on the ground (Trémolet and Rama 2012). Implementation variability is high in places where WASH improvements rely on a consortium of NGOs and community-based management or in areas that lack formal mandates of service delivery (Sharma et al. 2010). Households and communities regularly take on management responsibilities and finance two-thirds of all WASH services, with many of these investments coming through self-supply solutions such as private wells, water tanks, pit latrines, or septic tanks (WHO/UN Water 2017). The diversity of service providers creates more opportunities for implementation failure where interventions are not delivered as intended and for decision-making that is not driven by theory and evidence. As is the case with much of the health and development sectors, there has also been limited attention to whether the implementing organizations themselves are sufficiently capacitated to innovate and adapt, and whether the funding mechanisms have even encouraged local adaptation.

IS Principles That Respond to the Complexity of WASH Provision

We recommend that the sector adapt three guiding IS principles to help address the complexity of WASH provision. The first is to conduct "pragmatic" research that reports on the "how" and "why" of intervention impact. This work requires researchers to fit methods to research questions and not vice versa, thus necessitating an appreciation for the full suite of available study designs. The application of hybrid effectiveness-implementation trial designs, economic evaluation, modeling, and process evaluations based on established theories of change would support questions on the means and rationales of intervention impact, adherence, and fidelity (Bauer et al. 2015). Second, we recommend routine use of established IS theories, frameworks, and models to understand context, design theory-based interventions, and document and evaluate interventions. This IS principle aids in understanding the generalizability of interventions and communicating implementation research using a shared language. Finally, we recommend co-creating knowledge with local policymakers, practitioners, and constituents to better align research questions with the needs of service providers at multiple levels and design theory-based interventions around the relevant interests of stakeholders (e.g., beyond health end points). This practice of co-creation may also improve the uptake of findings by conducting research under more real-world conditions and build IS capacity among stakeholders to sustain implementation research. All three recommendations will require the application of new tools and training but also will require new funding opportunities that prioritize this modality of learning and collaboration. We expand on these principles and describe their relevance and application to the sector below.

Adapt "pragmatic" research models. Studies that show causal inference of an intervention (e.g., experimental and quasi-experimental designs) are stressed as a precondition for interventions to be eligible for investment and replication (Woolcock 2013). However, research with this sole purpose often underreport the contextual and operational factors surrounding interventions, which are arguably the most important for guiding policy and practice at scale (Luoto et al. 2014). Experimental trials by design remove "local details" that inform how a program worked (Berwick 2008). Operational monitoring of individual projects may provide more detail on understanding if an intervention is working but often center around a specific context, without regard to how successes and challenges are related to the generalizability of the approach or for sectorwide learning. In many ways this is analogous to the debate between studies that prioritize internal validity over external validity (Victora et al. 2004). We believe that both approaches are necessary but insufficient for building the evidence base for guiding WASH policy.

Implementation scientists aim to understand *how*, not merely *whether*, programs achieve anticipated gains. The deficient documentation of WASH intervention development and delivery and the lack of rigorous process evaluations that relate implementation outcomes to intervention effectiveness make it difficult to identify whether failures to achieve health gains are due to failures in implementation, theory, or both. In the case of several recent WASH and nutrition trials, intervention fidelity was high, but compliance by beneficiaries was inconsistent, so it is possible that the underlying theory of change, specifically for technology choice and behavior change strategies, for these interventions was flawed (Cumming et al. 2019; Pickering et al. 2019; Whittington et al. 2020). In addition, WASH studies may target populations or deliver interventions that lack external validity, meaning that they are not conducive to guide global policy. For example, the WASH-Benefits trial in Kenya worked in areas with higher sanitation access and little water scarcity, limiting its application to understanding an important programmatic and policy question: the impact of improved water quantity or sanitation in areas with lower overall access (Null et al. 2018).

Trial results are often more actionable if they incorporate findings on the implementation and translation processes (Glasgow et al. 2012). This methodology requires attention beyond individuals receiving the intervention, and an emphasis on intervention delivery, including documenting specific activities, implementing organizations, surrounding political/environmental/social settings, and effects on implementation outcomes over time. These details could be examined using different methods, such as pragmatic trial designs, process evaluation, comparative case study analysis, modeling, cost–effectiveness analysis, or qualitative data collection as part of the intervention delivery process.

For example, process evaluations document the intervention and assess basic implementation outcomes against clearly articulated delivery protocols. They can also help to validate the hypothesized theory of change, which is especially useful for explaining any null effects (Saunders et al. 2005). Validation does not necessarily mean to homogenize the specific components of interventions but to regiment their fundamental processes and functions for improved external validity of the

intervention design across settings (Hawe et al. 2004). Few WASH studies use process evaluation for this purpose. Going back to an earlier sanitation example, the *Handbook on CLTS* stresses the importance of pragmatism, providing general guidance on the core components of the behavior-change program but few standards on how to deliver components, because those should depend on local context (Kar and Chambers 2008). This implementation variability makes it difficult to evaluate CLTS as a single program (Venkataramanan et al. 2018; Zuin et al. 2019); however, it is still possible to test the underlying theory of intervention components, evaluating them against their ability to effect implementation outcomes over time. Strengthening this type of evidence may improve the sector's capacity to design theory-driven interventions across contexts.

Optimizing delivery is especially relevant for scaling WASH interventions that are efficacious but costly to scale. There are several IS research designs used to specifically test and adjust implementation strategies for improved outcomes in cost, uptake, maintenance, etc. Pragmatic hybrid trial designs test the effectiveness of an intervention in the context of competing implementation strategies, which can also integrate cost-effectiveness evaluation (Brown et al. 2017; Peters et al. 2013; Theobald et al. 2018). For instance, health effects of point-of-use chlorination are only observed in trials that report daily to fortnightly contact between behavior-change promoters and study participants (Pickering et al. 2019). A hybrid trial could compare varying "doses" of promotion on implementation outcomes to design a more scalable intervention. Sequential multiple assignment randomized trial (SMART) designs are a way to adapt interventions and compare different intervention options during evaluation, particularly adjusting components or the intensity/dosage of an intervention depending on the study participants' response (Lei et al. 2012; Almirall et al. 2012).

Systems science also offers methods (e.g., network analysis, system dynamics, agent-based modeling) to examine nonlinear processes in changing interactions and implementation outcomes and simulate alternative implementation targets across myriad contexts (Truscott et al. 2017; Rosenthal et al. 2020). Quality improvement studies provide structured methods for involving all stakeholders to iteratively plan, execute, and analyze new ways of improving performance (Brown et al. 2017). This study type has proven to be useful for codesigning handwashing interventions with local service providers by rapidly piloting and optimizing protocols in health care settings (Kallam et al. 2018). These different methods may help bridge the translation gap between outputs and impacts, specifically in improving our understanding of how to change and sustain behaviors and generalizability of interventions.

Use IS theories, frameworks, and models throughout the research process. The use of systematic models, both the application of behavioral theory and action planning frameworks, is a hallmark of IS research. Their use and reference provide structure and a shared language to better design, adapt, and evaluate interventions and facilitate learning among organizations (Tabak et al. 2012). Numerous and competing theories, frameworks, and models have emerged from the field, making it difficult to choose just one to discuss. Below we introduce the taxonomy of IS approaches and provide several examples of how established IS approaches could be used in the WASH context.

IS approaches can be organized into three general overarching objectives of the field (Nilsen 2015): *a*) articulating the determinants or influences of process/implementation outcomes (determinant frameworks, classic theories, and implementation theories); *b*) evaluating implementation (evaluation frameworks); and *c*) describing or guiding the process of translating knowledge into practice (process models).

The Consolidated Framework on Implementation Research (CFIR), for example, is a widely used *determinant framework* that can inform intervention selection and systematically identify possible barriers and facilitators for sustainable delivery. The CFIR harmonizes concepts across implementation theories into five major domains, allowing researchers to select CFIR constructs that are most pertinent to understanding their unique implementation setting and the "contextual fit" of an intervention (Damschroder et al. 2009). The intervention domain of CFIR includes constructs that consider all types of characteristics of the intervention, such as its origins of development, technological quality, complexity, and cost, and its adaptability to be altered and tailored for local needs (Damschroder et al. 2009). The CFIR's *outer setting* domain touches on economic, political, and social forces that influence the implementation of the intervention. For example, project timelines could be too short to meet desired outcome or impact as a result of election or budgetary cycles. The feasibility to meet something like water quality standards could also depend on a jurisdiction's institutional and legal framework for assigning and enforcing liabilities among the mix of service actors. Outer-setting factors are sometimes beyond a local implementer's control, but they should at least be accounted for during program design.

The CFIR's inner setting domain, in contrast, describes much of the operational constructs of the service provider. Here, one can think of characteristics of the provider such as the experience, maturity, culture, and skills capacity. Implementation scientists may also further assess institutional capacity by using other frameworks based on organizational theory regarding "readiness for change" (Helfrich et al. 2011). During effectiveness trials, interventions are sometimes delivered by a highly trained team with ample resources for monitoring and ensuring high fidelity to the intervention (Alonge et al. 2019; Brown et al. 2017). For example, the Sanitation Hygiene Education and Water Supply in Bangladesh (SHEWA-B) program aimed to improve WASH behaviors for 20 million rural Bangladeshis. Although SHEWA-B's design was proven effective in rigorous pilot studies, the scaled program was able to improve only a few targeted behaviors and did not significantly improve child health (Huda et al. 2012). Program evaluators speculated that the program's shortcomings were in operational delivery, because contracted NGO promoters did not have sufficient training and practical monitoring strategies were underdeveloped (Huda et al. 2012). Use of the CFIR or readiness assessments could support predictions of organizational shortcomings.

Implementation theories are especially useful for designing interventions. COM-B (Capacity-Opportunities-Motivation-Behavior), a widely used tool, adapts 19 behavioral theories from multiple disciplines into one instrument for planning behavior-change innovations (Michie et al. 2009). COM-B has been applied in the WASH sector to guide formative research and design novel WASH innovations for improving behavior outcomes in caregiving practices, safe feces management, and hygiene (Caruso et al. 2019; Delea et al. 2019; Freeman et al. 2020). There are also some established behavioral models specifically developed in the WASH sector, including the Integrated Behavioral Model for WASH (IBM-WASH) (Dreibelbis et al. 2013), RANAS (risks, attitudes, norms, abilities, and self-regulation) (Mosler 2012), and the Evo-Eco approach (Aunger and Curtis 2014). Determinant frameworks and implementation theories could be more widely used and documented in sector research, specifically to inform intervention development and to sufficiently detail an intervention's proposed theory of change.

Evaluation frameworks identify possible indicators for objectively measuring successful implementation. In an attempt to

systematize process outcomes, Proctor et al. (2011) outline eight dimensions of implementation outcomes that include acceptability, adoption, appropriateness, feasibility, fidelity, implementation cost, penetration, and sustainability, each with potential units of analysis and methods for measurement. RE-AIM (an acronym for Reach, Effectiveness, Adoption, Implementation, and Maintenance) is a frequently used evaluation framework that is more operationally focused (Glasgow et al. 1999). These frameworks are possibly convenient for designing program checklists/diagnostics, monitoring and evaluation methods, and performance-based contracts for implementing partners.

Process models attempt to illustrate the steps needed for disseminating and translating knowledge. They may be valuable for knowledge mapping and planning organizational research agendas and scientific communication. We have not found an example of a process model used by a WASH implementer or funder; however, there are a few examples used by related research organizations. The U.S. Centers for Disease Control and Prevention (CDC) promotes the Knowledge to Action (K2A) framework for achieving individual and organization uptake of an evidence-based intervention (Wilson et al. 2011). The three distinct phases are the research/discovery, translation, and institutionalization phases, all of which have their own decision points and supporting structures for moving knowledge to action (Wilson et al. 2011). The U.S. National Institutes of Health integrate the Glasgow et al. (2012) translational phases of dissemination and implementation science research, which define the cyclical, interrelated process of moving research into policy. Figure 2 simplifies the primary objectives of the translational phases. The preliminary phase (T0) describes identification of the problem and new discoveries, including formative research, monitoring data, capacity assessments, and diagnostics. The first phase (T1) includes behavioral trials and rapid testing of an intervention in a new context. The second phase (T2) includes a set of studies and trials that extend along the intervention-impact chain, focusing on internal validity and efficacy. The third and fourth stages (T3 and T4) are on improving activity–output–outcome by focusing on fidelity of the intervention and testing effectiveness studies in different contexts to improve effectiveness and cost effectiveness.

Rather than recommending any particular IS framework, theory, or model when designing programs and studies, we instead advocate for WASH stakeholders to consider applying the structured IS approaches that are most contextually appropriate. We caution that IS was principally developed for clinical settings in high-income contexts, and adaptation to nonhealth system delivery and LMICs is just now emerging. Nevertheless, the approaches are still relevant to WASH, and its application is not merely an academic exercise. We believe the application is practical to integrate policy, program, and learning from stakeholders and to improve effective scale and replication of successful interventions and innovations. The application of these frameworks and models will require building capacity of stakeholders regarding their use. These tools can be applied from initial scoping of context and the use in formative evaluation describing the intervention components and fidelity and compliance of delivery.

Co-create knowledge with multiple stakeholders. Global health advocates of implementation science have underscored the necessity of collaboration among researchers, policymakers, implementers, and communities for building and using the knowledge base (Alonge et al. 2019; Theobald et al. 2018; Holt and Chambers 2017). Environmental health research generally supports this principle, such as in the promotion of community-based participatory research methods for addressing environmental exposure concerns of community residents (O'Fallon and Dearry 2002). Yet, a review on global health studies claiming IS applications found that efforts to involve diverse stakeholders were infrequent, with few examples of comprehensive discussions on policy implications (Alonge et al. 2019). This collaboration is critical for proposing relevant research questions on implementation, designing theory-driven and context-specific interventions, and increasing the probability of conducting research under real-world conditions that are not heavily influenced by research teams (Holt and Chambers 2017; Alonge et al. 2019). Involving the multitude of constituents in the entire research process may also importantly foster shared ownership and improve the transfer of scientific skills for building local research capacity and strengthening monitoring and management of information systems. The WASH sector

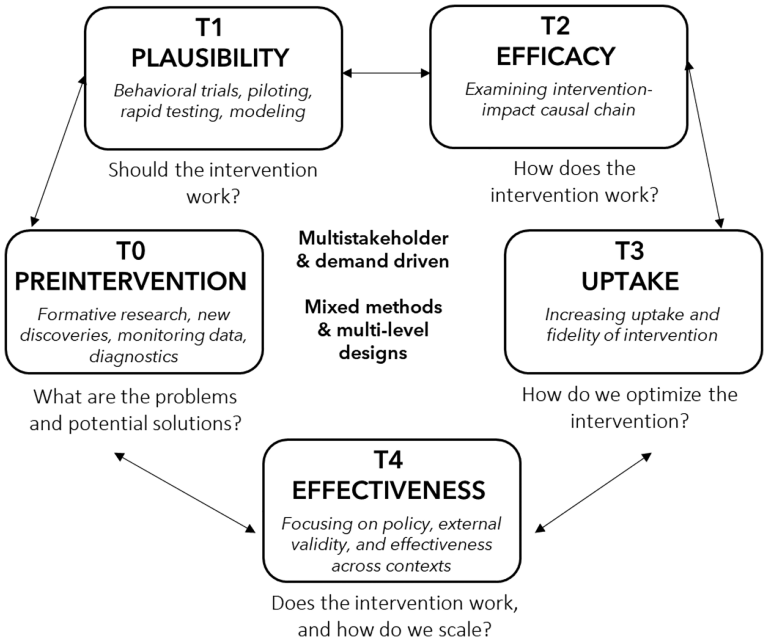

Figure 2. Translational Phases of Evidence to Practice (adapted from Khoury et al. 2010 and Glasgow et al. 2012).

has many examples of multisectoral and multistakeholder collaboration, but the sector can strive to better institutionalize and document collaboration for its replication in other contexts. However, we stress that it is essential that researchers possess the competencies needed to work with communities, such as positive attitudes toward community engagement and willingness and capability to gain knowledge about the community and collaboratively conduct research (Shea et al. 2017).

Discussion

Water and sanitation are deemed to be human rights, and donor and government funds should rightly continue to support improvements in WASH access for the billions of people who remain underserved (WHO/UNICEF 2019). There are decades of experience implementing WASH interventions in resource-poor regions, yet approaches to adapting, scaling, and sustaining WASH access and behaviors remain elusive. Recent large-scale health impact studies have highlighted challenges in effectiveness of available interventions and potential health gains from WASH investments (Cumming et al. 2019; Pickering et al. 2019; Whittington et al. 2020). New discoveries for enhancing health slowly or seldom deliver their promised impact because their uptake is dependent on interactions between individuals and organizations housed in multifaceted social contexts (Aarons et al. 2011; Glasgow et al. 2012). Yet, donors and governments continue to invest in innovating new technology, despite the compelling argument that increasing uptake of existing evidence-based interventions—and a rigorous approach to learning—would be more cost-efficient and speed the reduction of health disparities (Glasgow et al. 2012; Woolf and Johnson 2005). This gap is partially explained by the lack of incentives to conduct implementation research in academia (Bromham et al. 2016).

But is the WASH sector ready for implementation science? Few would contest the strong biological plausibility that reduction in exposure to fecal pathogens improves health, and adequate WASH technologies and behaviors are key to that reduction. Yet it is reasonable to conclude that the empirical evidence for improvements to health are from higher-income settings (Cutler and Miller 2005), where WASH improvements have been successful at reducing transmission along a narrower set of transmission pathways than those faced by children in lower-resource settings. And as such, the WASH sector operating in these lower-resource settings is not yet ready for the tools of implementation science to document, adapt, and scale proven interventions. However, there have been successes in implementation and on the impact of WASH interventions on health, even if the evidence across all studies is mixed (Freeman et al. 2017; Prüss-Ustün et al. 2019; Wolf et al. 2018). Many countries were able to meet sector targets by 2015, nearly eliminating the dependence on lakes, rivers, and unprotected surface water sources for drinking and the once-widespread practice of open defecation (WHO/UNICEF 2019). There is evidence to suggest that WASH technologies in LMICs have the potential to provide health and social benefits when they are used and well-maintained. On-premise water connections do reliably reduce the prevalence of diarrhea when continuously available and free of fecal contamination (Wolf et al. 2018). Point-of-use filter interventions have been widely used and scaled for improvements in child health (Kirby et al. 2019; Wolf et al. 2018). Demand-based WASH programs can effectively change sanitation and hygiene behaviors at the community level (Garn et al. 2017). We assert that it is imperative that we study the processes and surrounding contexts that enabled these interventions to be effective.

We do not intend to diminish the importance of measuring health and well-being outcomes in WASH research. Untangling the relationship between WASH conditions and health is essential for setting agendas and for innovation. Rather, we can improve the frame and scope of our research questions to match the sector's complexity. We argue that improvements to and standardization of process documentation, application of behavioral theory for development of implementation strategies, the application of flexible design and evaluation approaches, purposeful approaches to adaptation, and awareness of organizational readiness for change could support both improvements to sustained delivery outcomes and measurable health gains at scale. Greater attention to improving uptake, functionality, and accessibility also supports the sector's multiple development end points past reduced diarrheal disease. WASH results in other health and nonhealth gains, including reduced respiratory infections and neglected tropical diseases and improved dignity and security, mental well-being, gender equity, and climate resilience, to name only a few (Prüss-Ustün et al. 2019; Sclar et al. 2018). A focus on implementation outcomes may have downstream impacts beyond specific health end points.

We recommend adapting more pragmatic research models by using the full suite of study designs—beyond traditional RCTS—to inform policy and practice and conduct these studies with rigor that appreciates the importance of external validity. In parallel, we recommend the use of systematic IS approaches throughout the design, documentation, and evaluation of interventions. Use of process models to guide research agendas may help to communicate and translate key learnings into practice [e.g., K2A, (Glasgow et al. 2012)]. Using established behavioral theory [e.g., COM-B, (Michie et al. 2009)] and determinant frameworks to map formative findings to proper intervention functions [e.g., the CFIR, (Damschroder et al. 2009)] may help to describe contextual fit of interventions and develop and test new innovations. Evaluation frameworks [e.g., RE-AIM, (Proctor et al. 2011)] can improve systematic assessment of program fidelity to report implementation success. Co-creating knowledge with multiple stakeholders will help focus research on local decision-making and needs of implementers and increase local research capacity.

The WASH sector can be seen equally as either a set of intervention outcomes (e.g., WASH access) searching for a health impact (e.g., diarrhea, stunting), or a set of human rights outcomes without the need for an infectious disease-related health impact. We believe at this moment that health-specific trials are not the highest priority to address the knowledge gaps in the sector; rather, nimble yet rigorous IS research could provide valuable actionable, policy-relevant guidance. We argue that a dedication to the fundamentals of IS in the sector would support the effective, context-specific application of evidence-based approaches and engender more policy- and programmatically relevant questions that focus on improving implementation outcomes in the WASH sector.

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