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Integrating Science and Engineering to Implement Evidence-Based Practices in Health Care Settings

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Abstract

Integrating two distinct and complementary paradigms, science and engineering, may produce more effective outcomes for the implementation of evidence-based practices in health care settings. Science formalizes and tests innovations, whereas engineering customizes and optimizes how the innovation is applied tailoring to accommodate local conditions. Together they may accelerate the creation of an evidence-based healthcare system that works effectively in specific health care settings. We give examples of applying engineering methods for better quality, more efficient, and safer implementation of clinical practices, medical devices, and health services systems. A specific example was applying systems engineering design that orchestrated people, process, data, decision-making, and communication through a technology application to implement evidence-based depression care among low-income patients with diabetes. We recommend that leading journals recognize the fundamental role of engineering in implementation research, to improve understanding of design elements that create a better fit between program elements and local context.

Keywords

Evidence-based Practices; Generalizable knowledge; Implementation engineering; Implementation science; Knowledge Generation; Local knowledge; Science and Engineering

Introduction

Despite progress in harnessing multidisciplinary approaches to build an evidence base on effective interventions in health care (Bowling, 2009; Fixsen et al., 2005), there has been slow progress in implementing these evidence-based practices (EBPs; Aarons et al., 2011; Bickman, 2013; Hoagwood et al., 2013; Proctor et al., 2009; Wandersman et al., 2003). One salient problem has been the tailoring of EBPs to conform to local conditions. We believe that principles and paradigms from engineering can help program implementation by improving understanding of design elements that create a better fit between program elements and local context.

Science and Engineering

Von Kármán, a leading physicist and aerospace engineer during the early days of the U.S. space program articulated the distinction between science and engineering as follows:

> “Scientists study the world as it is; engineers create the world that never has been.” (American Society for Engineering Education, 1970, p. 476)

We see these as distinct, but overlapping and complementary disciplines. Science formalizes and tests innovations, whereas engineering customizes and optimizes how the innovation is applied. Together they may accelerate the creation of an evidence-based healthcare system.

Generalizable Knowledge and Local Knowledge

When building a bridge, the civil engineer needs to apply scientific principles (generalizable knowledge), such as the laws of Newtonian mechanics, fluid dynamics, material science, and sedimentology. Each bridge also presents a unique engineering task, in the same way that each health care setting presents a unique implementation task. The civil engineer needs to incorporate local knowledge specific to the setting, such as local geological conditions (soil and rock formation), meteorological and hydrological conditions (wind and flood), anticipated traffic patterns, and community development. Similarly, the execution of programs in health care must incorporate local knowledge, such as organizational culture, health care provider factors, financial constraints, resource availability (e.g., information technology support), and patient beliefs and attitudes, to accomplish the implementation engineering task. The integration of generalizable knowledge and local knowledge entails problem-solving skills that adapt and improvise to accommodate the prevailing local conditions.

The distinction between generalizable knowledge and local knowledge lies in the intent: generalizable knowledge is intended for “universal consumption” by a broad target population, including those who did not participate in the original research study; local knowledge is intended for “local consumption” in a specific setting for the involved local population. Although the methods used to produce the two types of knowledge might be similar, health care research and existing funding mechanisms for effectiveness research tend to emphasize the generalizability of results (known as the external validity) without elaborating on the details specific to its implementation.

Examples of Implementation Engineering

Examples of implementation engineering are emerging, such as those from the Veterans Health Administration (VHA) through its Veterans Engineering Resource Centers (VERCs). These centers partner with VA health services research centers and systems engineering experts at academic institutions to apply engineering principles to common problems in VHA healthcare delivery (Kim et al., 2013; Peck et al., 2012; Shi et al., 2013). The NIH Clinical and Translational Science Award program encourages incorporating bioinformatics as an engineering means for translating clinical research into practice. Below, the authors apply first-hand knowledge to illustrate the integration of science and engineering in the implementation of evidence-based practices.

DCAT Study

The Diabetes-Depression Care-management Adoption Trial (DCAT) is a comparative effectiveness trial conducted through a collaboration between faculty in the University of Southern California Viterbi School of Engineering (XXXXX, project PI), School of Social Work, and Keck School of Medicine in partnership with the Los Angeles County Department of Health Services (Wu & Ell et al., 2014). The DCAT study compared three approaches for adopting the evidence-based practices of depression screening, symptom monitoring, and antidepressant medication optimization among low-income patients with diabetes. One approach incorporated a collaborative, team-based depression care intervention into a diabetes disease management program (IMPACT, developed by Drs. Jürgen Ünützer and Wayne Katon; http://impact-uw.org/). The second approach tested a technology-enhanced disease management program that incorporated engineered technology to facilitate the disease management program’s adoption of collaborative depression care. The third arm of the study was a control group of usual primary care practices for diabetes and depression treatment.

The DCAT team engineered a technological solution to assist time-pressured health care providers by routinely screening and monitoring their patients for depression symptoms, treatment adherence, and communication needs (Wu & Vidyanti et al., 2014). The solution included a fully automated telephonic assessment system that was linked with patients' disease management registry to trigger depression care management calls based on patient medical records, call history, and personal preferences. Telephone was selected as the communication platform because phones are the most accessible technology among the low-income population. The calls were low-intensity, i.e., every month or every three months based on patient's depression condition, to balance the information need and patient burden. Since patients who are depressed are more likely to miss their scheduled visit appointments; and patients with depression often delay - or altogether forgo - calling for help when symptoms fail to improve or worsen, the study automated calls, with an alternative of having staff instead of machine, called patients rather than relying on them to initiate calls to proactively reach patients and identify their care need.

Assessment data were tethered to the registry for provider information. Based on predetermined clinical algorithms in the registry and the assessment data, task reminders and alerts were generated automatically to prompt certain providers to follow up with specific patients in need of care (e.g., tasking a care manager to follow up with a patient who self-reported poor medication adherence, or tasking a social worker to follow up with a patient with major depression symptoms). Task reminders included structured, radio-button lists of care management actions that could be taken by provider role (e.g., nurse case managers, clinical social workers), with the option of free text, to support evidence-based practices and to ease providers' documentation burden.

The system deployment initially faced resistance from the study sites because the clinicians' concerns about lack of fail-safe system for responding to patients' suicidal ideation detected by the automated assessment was insufficiently sensitive to ensure clinical intervention for suicidal patients. Therefore, the study team engineered a suicidal alert mechanism in the system to alleviate the implementation barrier. When a patient expressed ideation of suicide or self-harm in an assessment, the call system automatically sent suicidal alerts via text messages and emails to a team of emergency responder physicians, one physician at a time at pre-established time intervals until a physician responded and contacted the patient. This "waterfall" approach facilitated timely contact with the patient to mitigate the risk of suicide and resulted in buy-in from the clinicians to partner on the study.

At 6 months follow-up, patients in the technology-enhanced disease management program showed significantly better outcomes (at $\alpha = .05$) than patients in the other two comparison groups, including lower Patient Health Questionnaire (PHQ)-9 depression scores (indicating better health). Patients in the technology-enhanced program were less likely to have major depression, were more likely to reach remission, and had less self-reported disability. These patients were also more satisfied with their diabetes care, had improved A1c and cholesterol levels, and made fewer emergency room visits.

A survey of 12 providers in the study showed that the seven providers in the intervention arm more frequently spent time providing care (e.g., monitoring adherence to treatment and side effects and adjusting the treatment plan), whereas the five providers in the other two comparison groups more frequently spent time identifying patients' care needs (e.g., routine screening and assessing for depression episodes). Provider outcome expectancy and satisfaction were significantly higher in the intervention group than providers in the two groups. Self-efficacy and familiarity with depression care were not different among providers. The findings suggest an engineered system change may result in changes in provider confidence and satisfaction without impacting their skills or beliefs (Di Capua and Wu, 2014).

As health care delivery systems are looking for ways to provide patient-centered care and improve quality for large chronically ill populations in an efficient, economical manner—especially as enrolled populations are set to expand dramatically with health care reform—DCAT provides an example of engineered health care delivery through the assistance of automated technology.

Johns Hopkins University Collaborations

A second example comes from the Applied Physics Laboratory, the Whiting School of Engineering, and the Johns Hopkins health professional schools and Johns Hopkins Health System. These four entities have collaborated to apply engineering approaches to improve health care through structured interactions and collaborative projects. To establish bridges across the University, both the School of Public Health and the School of Medicine hired human factors and computer science engineers.

One project aims to solve the lack of integration among the hundreds of pieces of equipment in the typical intensive care unit (ICU). Currently the devices are not interoperable and do not communicate with one another, creating information gaps, duplication of work, and preventable errors. Project Emerge aims to create a more efficient and better-coordinated ICU, using a team that includes engineers from the Whiting School of Engineering and Lockheed Martin as well as computer scientists, behavioral scientists, physicians, and communications specialists (Desmon, 2012).

In a second project, an interdisciplinary research team used human factors methods, including prospective hazard identification methods, to collect data for 22 cardiac surgeries in five hospitals. Thematic analysis of the qualitative data, guided by a work system model, revealed 60 categories of hazards such as practice variations, high workload, noncompliance with guidelines, and failure to include clinicians in medical device purchasing (Gurses et al., 2012).

Additional projects include the institution of a human factors laboratory for the testing of new “smart” infusion pumps and other devices before widespread deployment in the health system, and a human factors engineering study of the work flow for radiation therapy to reduce the incidence of failures and harm (Terezakis et al., 2011). These various projects apply engineering principles and methods for better quality, more efficient, and safer implementation of clinical practices, medical devices, and health services.

Local Knowledge and Case Reports

Studies designed to promote local knowledge are akin to case reports, the original form of scholarship published in medical journals. A study that measured medication error rates before and after providing nurses on a medical-surgical ward with “do not disturb” vests to increase their ability to focus on specific tasks (Relihan et al., 2010) was an example of human factors engineering applied to a real-world health care challenge. But seemingly more rigorous experimental designs gradually supplanted case reports, so now it is almost impossible to publish case reports. In a reversal of this trend, some new journals such as *BMJ Case Reports* (since 2008) and the *Journal of Medical Case Reports* (since 2007) devote their content exclusively to case reports. Published case reports are valuable not because they are a repository of generalizable knowledge (they are not), but because they (a) provide practitioners and researchers with specific examples of addressing local health care problems that may provide insights for future work and (b) provide methodological models for applying interventions to real-world health care settings. That said, major academic journals classically measure their own impact as a function of journal citations and are generally resistant to publishing clinical case reports.

We believe it is important for the field of implementation and its leading journals to reexamine the yardstick to be used to measure their accomplishments. Should impact factor based on academic journal citations be the ultimate goal for the field of implementation? We believe that to build a better health care system, impact should be measured at least in part by patient outcomes, safety, and satisfaction. An innovative implementation of a known technology that reliably delivers safer care should be considered an important breakthrough, be widely disseminated, and earn academic respect.

Conclusion

The principles and practices from engineering could be utilized to advance system reform and implementation science. In the interest of implementing evidence-based practices in health care settings, we recommend that researchers collaborate with engineers to advance the impact and range of healthcare innovations.

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