A Framework for Selecting Digital Health Technology

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Executive Summary

The Patient Protection and Affordable Care Act (ACA) in the US has accelerated a transition from volume- to value-based care. Part of this whole system redesign has included a rapid proliferation of digital health technology. This growing trend is reflected by over $1.4 billion invested in 2012 and the 25 percent increase in number of investments in 2013 over a comparable period in the preceding year. Despite the rapid proliferation of digital health innovation, there remains little guidance facilitating the selection of technologies that drive value-based care.

The Triple Aim framework, developed by the Institute for Healthcare Improvement (IHI), describes an approach to optimizing health system performance to improve the health of populations by simultaneously improving the patient experience of care, improving the health of populations, and reducing the per capita cost of health care. As the health care landscape shifts toward population health management and enacted policies work to curb the rising cost of health care, emerging digital health technologies should seek to realize the Triple Aim.

Using validated approaches to software selection, we created a Digital Health Selection Framework (DHSF) to guide patients, providers, and payers through the procurement of technology to help them achieve the Triple Aim.

The framework and our analysis reveal multiple trends that suggest a failure by developers to address market demand for evidence-based technology that achieves the Triple Aim. Future work is needed to confirm and characterize if there is an ongoing market failure, its causes, and possible remedies. Particular attention should be paid to the role of 1) externalization of value to public payers like Medicare and Medicaid, 2) reestablishing market equilibrium by aligning technology reimbursement with consumers' demand rather than grant programs' priorities, 3) public and private investment in technology to support technology development as the market failure is resolved, and 4) further exploration to identify how to eliminate market inefficiencies.

Our analysis suggests that investment in digital health often occurs independent of evidence, technology type, or consumer target. With no significant association between investment level and level of evidence, these data appear to contradict the common practice among entrepreneurs to prioritize setting up research pilots to create evidence for their technology.

The most striking finding of the DHSF is that the vast majority of digital health companies do not simultaneously emphasize achievement of all three components of the Triple Aim. This may reflect a lack of awareness or perceived value of the Triple Aim for health technology entrepreneurs. It may also indicate a market in transition from technology products that currently serve dominant fee-for-service, volume-driven health care organizations toward serving value-driven delivery and reimbursement models. The gaps identified in this analysis offer a glimpse into the unique design challenges and opportunities for entrepreneurs, investors, and other innovators to anticipate market demand for creating technology that will more comprehensively achieve the Triple Aim.

Intent and Aim

The intent of this 30-day IHI Innovation Project, conducted in the summer of 2013, was to scan for health technology innovations that will provide the greatest value to health systems working to achieve the IHI Triple Aim.

Background

Spurred by the Patient Protection and Affordable Care Act (ACA) in the US, health care payment and delivery reform is driving a transition from volume- to value-based care.[1] Part of this whole system redesign has included a rapid proliferation of digital health technology.[2] Digital health is an umbrella term that can include the technologies referred to as mobile health (mHealth), health information technology (HIT), telehealth, Big Data analytics, personalized medicine, genomics, quantified self, wearable computing, and connected health, among others.[3] The growth of digital health is further enabled by the expansion of Internet connectivity,[4] adoption of highly scalable approaches to software distribution,[5] and emerging rapid-cycle approaches to software development.[6] The increasing interest in digital health is reflected by over $1.4 billion invested in 2012 and the 25 percent increase in number of investments in 2013 over a comparable period in the preceding year.[7]

Despite the rapid pace of digital health innovation, best practices to facilitate the selection of technologies that drive value-based care are relatively limited.[8] Emerging resources provide reviews of certain types of digital health technology, but they are limited in scope. For example, mHealthEvidence.org by Knowledge for Health (K4H) is one of the first attempts to develop a database that provides an overview of gray and peer-reviewed evidence of mobile health technologies. The prevailing databases of digital health technologies are limited by subgenre and they are mainly descriptive in nature. Despite these emerging resources, most procurement practices in digital health are informed by traditional means: word of mouth, Internet search, and consultant or expert opinion. A recent study found that only 19 percent of commercial-off-the-shelf software (COTS) procurement by health care organizations was guided by a formal decision-making method.[9] The existing warehouses of digital health technology lack a comparative or analytic lens that would allow discrimination between available technologies on the basis of evidence about impact on population health, individual health, or costs.[10,11]

The Triple Aim is a framework developed by the Institute for Healthcare Improvement (IHI) that describes an approach to optimizing health system performance to improve the health of populations. IHI advocates for delivery innovation to be aligned with the three dimensions of the Triple Aim: 1) improving the patient experience of care; 2) improving the health of populations; and 3) reducing the per capita cost of health care.[12] As the health care landscape shifts towards population health management and enacted policies work to curb the rising cost of health care, new HIT should help to drive the Triple Aim.

There is no currently available evidence-based or evidence-informed framework to guide the selection of digital health technology that will help end users achieve the Triple Aim. Using validated approaches to software selection, we created a Digital Health Selection Framework (DHSF) to guide patients, providers, and payers through the evaluation and procurement of technology to help them achieve the Triple Aim.

Methodology

In order to derive a framework that organizations could use to identify and validate Triple-Aim-enhancing technologies, we used a validated approach to software selection called Context-driven Component Evaluation (CdCE) process.[13] The CdCE process provides a framework for selecting technologies by filtering, evaluating, and ranking them based on their ability to meet an

organization's or individual's specific needs (Table 1). To create the DHSF, we adapted the CdCE process to guide selection of digital health software applications.

Table 1. Adaptation of the Context-driven Component Evaluation (CdCE) Process

Step 1	Select inclusion criteria for evaluating technology options
Step 2	Create a short list of candidate technologies
Step 3	Create the process for evaluating the short list of technologies
Step 4	Refine the process for evaluating the short list of technologies
Step 5	Apply the evaluation process to each candidate technology
Step 6	Analyze the results of the evaluation process
Step 7	Rank the candidate technologies based on their performance
Step 8	Report the results

1. Select Inclusion Criteria for Evaluating Technology Options

The first step of the DHSF was selecting inclusion criteria for evaluating technology options (Table 2). Inclusion criteria were initially chosen based on the expert opinion of the authors relative to their professional experiences in quality improvement (KM, ND), digital health innovation (AO), and clinical practice (KM and AO). The criteria were then vetted by a series of interviews with stakeholders, including patients, clinicians, and management executives working for health care providers, and management executives working for payers.

Table 2. Technology Evaluation Inclusion Criteria

1	Triple Aim Component: Improve Patient Experience, Improve Population Health, Decrease Per Capita Cost of Care
2	Level of Evidence: Evidence-based, Evidence-informed, Emerging (see Table 3)
3	Investment Level: Based on level of funding
4	Technology Type (see Table 4)
5	End User: Patient/Consumer, Provider, Payer (see Table 5)

2. Create a Short List of Candidate Technologies

Next, we created of a short list of candidate technologies to be evaluated based on an availability sample of the Startup Health Insights database. Startup Health is a global startup platform with the aim of accelerating digital health innovation. The Startup Health Insights database is a

comprehensive funding database tracking over $8 billion in digital health and health technology business transactions deals from January 2010 to June 2013.[14] The database included the following standard funding rounds: Incubator, Seed, and Series A through F Venture Rounds.

3. Create the Initial Process for Evaluating the Short List of Technologies

The process for evaluating the short list of technologies was based on the Cochrane Handbook for Systematic Reviews and on the authors' expert opinions.[15] Prior to conducting an evaluation of the full Startup Health Insights database, the authors (AO, ND, KM) conducted an initial unblinded review of a training set of 20 technologies to refine the subcategories for each of the inclusion criteria.

The initial process for evaluating the short list of technologies included a Google search of each company's name. Based on the first result in the Google search, the reviewers perused the company's website Home page, About page, and/or an equivalent subsection of the website for a description of the technology. If the description of the technology was consistent with the definition of digital health in the Background section above, then the website was fully reviewed. The categorization of each technology using the five evaluation criteria in Table 2 was based on direct claims made on each company's website.

For the purpose of this analysis, we focused on digital health technologies that created a new or improved an existing health care process, device, or system. If the technology was applicable to other industries, then a primary focus of the technology had to be on health care to be considered for inclusion in the analysis. Furthermore, the technology had to be actively functioning; any extinct technologies were excluded from the analysis. Fourteen of the 101 candidate technologies were excluded from the evaluation because they did not meet the inclusion criteria described above or met criteria for exclusion.

4. Refine the Process for Evaluating the Short List of Technologies

After the initial review of the technology short list, there was no modification of the inclusion criteria subcategories for the *Triple Aim Components*, which remained Improve Patient Experience, Improve Population Health, and Decrease Per Capita Cost of Care.

Conversely, we did expand the inclusion criteria subcategories for *Level of Evidence* to reflect the variability among the candidate technologies. The training set helped the authors to inductively identify the following subcategories: Evidence-based, Evidence-informed, and Emerging (Table 3). The *Level of Evidence* inclusion criteria expansion was driven by a review of the Press Release, Resources, About, and other comparable sections of each candidate technology's website. In particular, we searched for language including the key phrases "study," "research," or "evidence."

Table 3. Descriptions of Technology Level of Evidence

Evidence-based	Peer-reviewed publication showing impact on the Triple Aim
Evidence-informed	Peer-reviewed presentation such as at a conference; also includes gray literature such as industry expert report, credible case study, and/or white paper; required to have at least methodology and population description; single-person case study and testimonial not considered sufficient
Emerging	No evidence needed

The process for evaluating digital health technology was further refined by modifying the initial inclusion criteria of *Investment Level*. Since startups typically do not publicly disclose their economic performance or customer traction, we could not accurately assess *Investment Level* for each technology. In lieu of *Investment Level*, we chose to use *Capital Investment* based on the assumption that direct third party investment in a technology startup is aligned with the company's potential for the best return on investment and technology viability. For the purpose of this preliminary review, the short list of candidate technologies was limited to 101 companies with the most *Capital Investment*. *Commercial Traction* was a continuous variable, and we did not identify any subcategories for evaluation that would benefit this preliminary analysis.

In the review of the training set of technologies, we were also able to substantially expand the inclusion criteria subcategories for *Technology Type* (Table 4).

Table 4. Technology Type Descriptions

Population Health Management/Predictive Analytics	Technology to improve care coordination, care management, large-scale data interpretation, and population-level interventions or decision making; data at the level of the population rather than the individual patient
Hospital/Clinic Administration	Hospital, outpatient clinic, research entity, or pharmaceutical company using software to improve workflow or efficiency, billing or claims, personnel management, business or financial decision making, which is separate from direct clinical interventions
Telemedicine/Teleconsultation	Patient and clinician communicate directly through a technology to offer real-time or asynchronous clinical guidance from provider
Personalized Health/Quantified Self	Patient collects data about his or her own behavior or health and uses that data to measure or make changes in behavior to improve health
Remote Patient Monitoring	Technology provides data from a patient in their home environment and conveys that information to a clinician in a different location (of note, Remote Patient Monitoring entails noticing changes in an existing condition or is disease-nonspecific, whereas Diagnostic entails detecting a new state of health or new condition)
Enhance Patient/Consumer Engagement	Technology engages the patient to interact with other patients or change their behavior pertaining to consumption of health care or non-health-care-focused specific products or services that ultimately aim to improve wellness

Interoperability	Technology that allows at least two separate technology systems to communicate in a meaningful way
Device	Technology whose value is derived entirely or in part from the hardware component
Diagnostic	Technology that interprets biometric data and offers a diagnosis of a new disease process rather than just a change in physiologic status (of note, Remote Patient Monitoring entails noticing changes in an existing condition or is disease-nonspecific, whereas Diagnostic entails detecting a new state of health or new condition)
Clinical Decision Support	Provider is typically receiving clinical data and the software is helping the provider make a better clinical decision; typically, provider and patient are co-located; data is at the level of the individual patient rather than the population
Therapeutic	Technology with a primary focus on treating an ailment directly in the form of a pharmacologic agent or device

Similarly, the initial review of the short list of technologies helped to refine the inclusion criteria for the subcategories of *End User* (Table 5).

Table 5. End User Descriptions

Patient/Consumer	Direct recipient of care or their family members
Provider	Physicians, nurses, other clinicians, home care workers, provider organizations, inpatient or outpatient
Payer	Private insurance companies, employers, publicly administered insurance: Medicaid or Medicare, accountable care organizations

5. Apply the Evaluation Process to Each Candidate Technology

Once the process for evaluating technology was refined based on the training set of candidate technologies, the researchers (AO and ND) independently conducted a review of the 101 top-funded startups in the Startup Health Insights database in order to categorize them using the inclusion criteria in Table 2. We summarized the data using a frequency distribution of inclusion criteria and their subcategories. A separate researcher (KM) then reviewed the 101 technologies. The researchers (AO, ND, and KM) then reconciled differences in their categorization using an iterative process that incorporated evidence from the review and discussion among the researchers.

6. Analyze the Results of the Evaluation Process

The frequency distribution table from the evaluation process was loaded into JMP Pro v10 from SAS. Individual variables were initially analyzed alone to examine their distributions within the distribution platform. Pairs of variables were then evaluated in the Fit X by Y platform for either Mosaic plots with accompanying contingency tables (for pairs of categorical variables) or one-way plots (for the one continuous variable in combination with the other categorical variables).

Appropriate statistical tests (either Chi-squared or Analysis of Variance) were conducted to look for meaningful differences within each pair of variables. Lastly, using the 3D Scatterplot platform, groups of three-variable combinations were examined for clusters and trends to demonstrate where the preponderance of technology innovation is currently taking place and where opportunities might exist.

7. Rank the Candidate Technologies Based on Their Performance

Following the analysis, we ranked the candidate technologies based on 1) the most common clusters of inclusion criteria, and 2) each type of *End User* that has corresponding technology with the highest *Level of Evidence* and the most number of *Triple Aim Components*.

8. Report the Results

Pursuant to the CdCE process, we codified the DHSF and are reporting the results of its first application in this report.

Results

Triple Aim Component

The review of technologies reveals that 48 of 87 (55 percent) primarily focus on Improving Population Health, 25 of 87 (29 percent) focus on Decreasing Per Capita Cost of Care, and 14 of 87 (14 percent) focus on Improving Patient Experience (Figure 1). All four Remote Patient Monitoring technologies primarily focus on Improving Population Health. The largest focus on Decreasing Cost of Care comes from the 18 of 21 (86 percent) technologies that perform Hospital/Clinic Administration. Technologies that Enhance Patient/Consumer Engagement have the largest emphasis on Improving Patient Experience (9 of 13, or 69 percent). And only two of the 87 (2 percent) individual technologies meet all three *Triple Aim Components*; one technology, a Software as a Service (SaaS) platform, looks to increase price transparency and the second technology is a pharmacy management software system.

Figure 1. Number of Technologies by Triple Aim Component
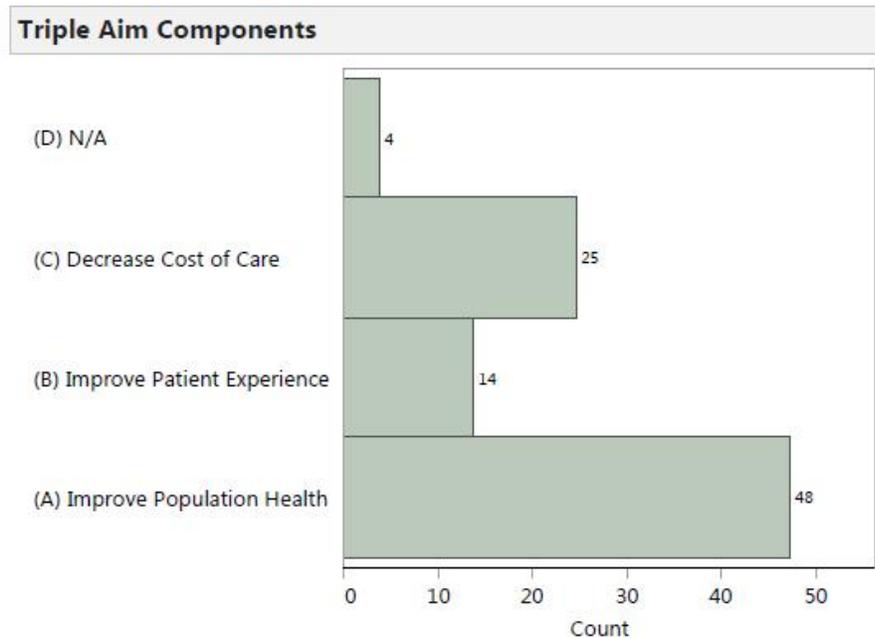
Level of Evidence

Only 20 of 87 (23 percent) technologies evaluated are Evidence-based, while 12 of 87 (14 percent) are Evidence-informed, and 57 of 87 (66 percent) are Emerging (Figure 2). All three Interoperability technologies and all three Telemedicine/Teleconsultation technologies that we reviewed have an Emerging *Level of Evidence*. Of the four Remote Patient Monitoring technologies, three are Evidence-informed and the other one is truly Evidence-based. None of the eight Payer-focused technologies are Evidence-based. Technologies aimed at Providers are the most Evidence-based, with 16 of 52 (31 percent) meeting our criteria (Figure 3).

Few companies show evidence backing their claim of Decreasing Cost of Care; only four of 25 (16 percent) claim to be Evidence-based or Evidence-informed. Technologies that are focused on Improving Population Health have the most evidence; 25 of 48 (52 percent) claim to be Evidence-

based or Evidence-informed (Figure 4). Digital health technologies with a focus on Diagnostics stand out as the most likely to be Evidence-based (5 of 6, or 83 percent).

Figure 2. Number of Technologies by Level of Evidence
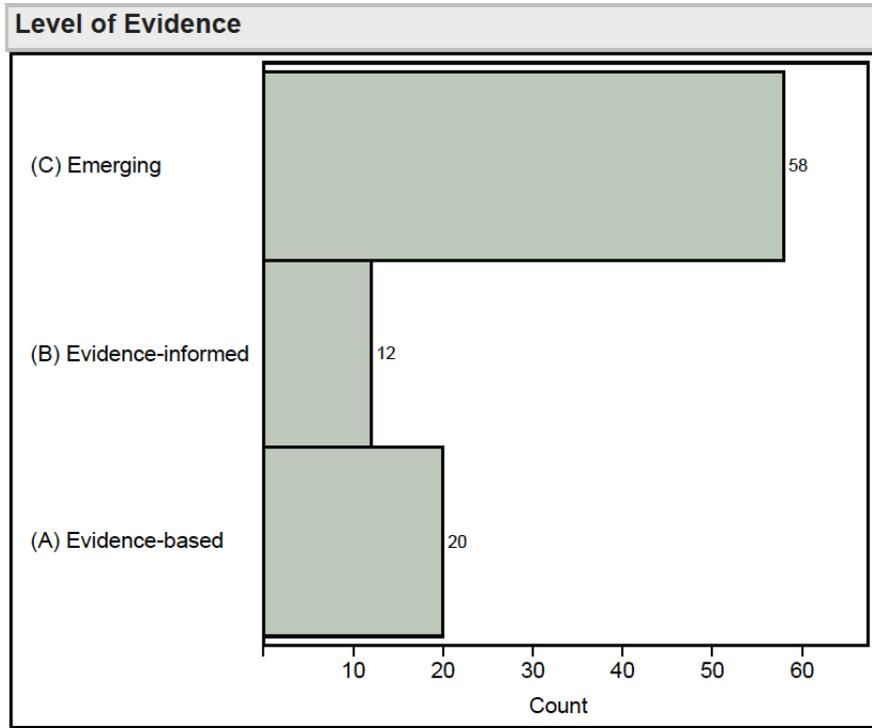
Figure 3. Mosaic Plot Showing Technology Level of Evidence by End User Type
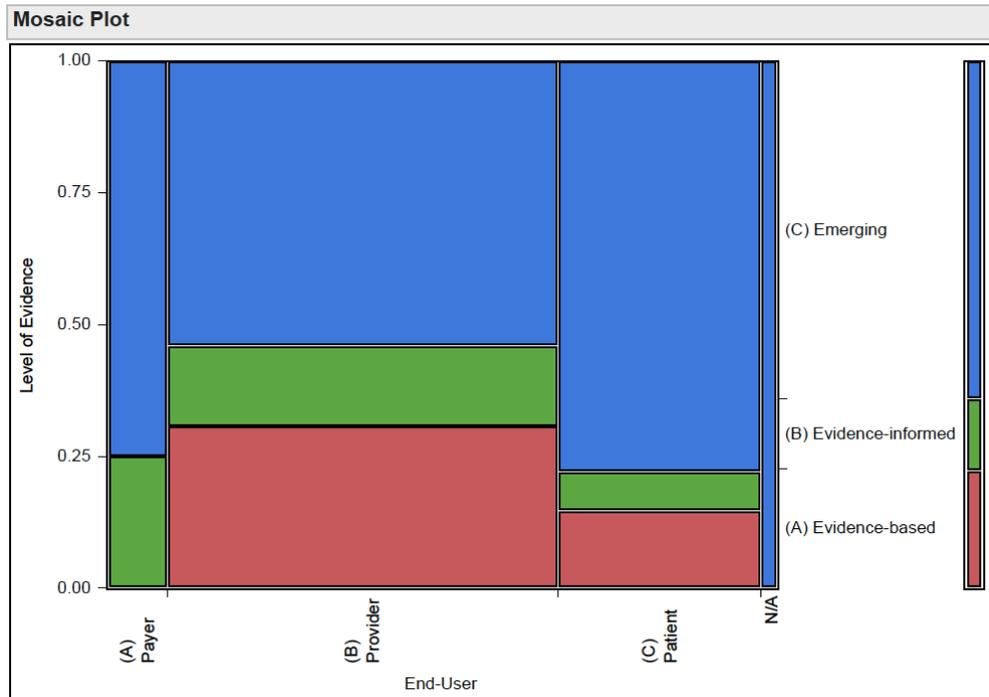
Figure 4. Mosaic Plot Showing Technology Level of Evidence by Triple Aim Component
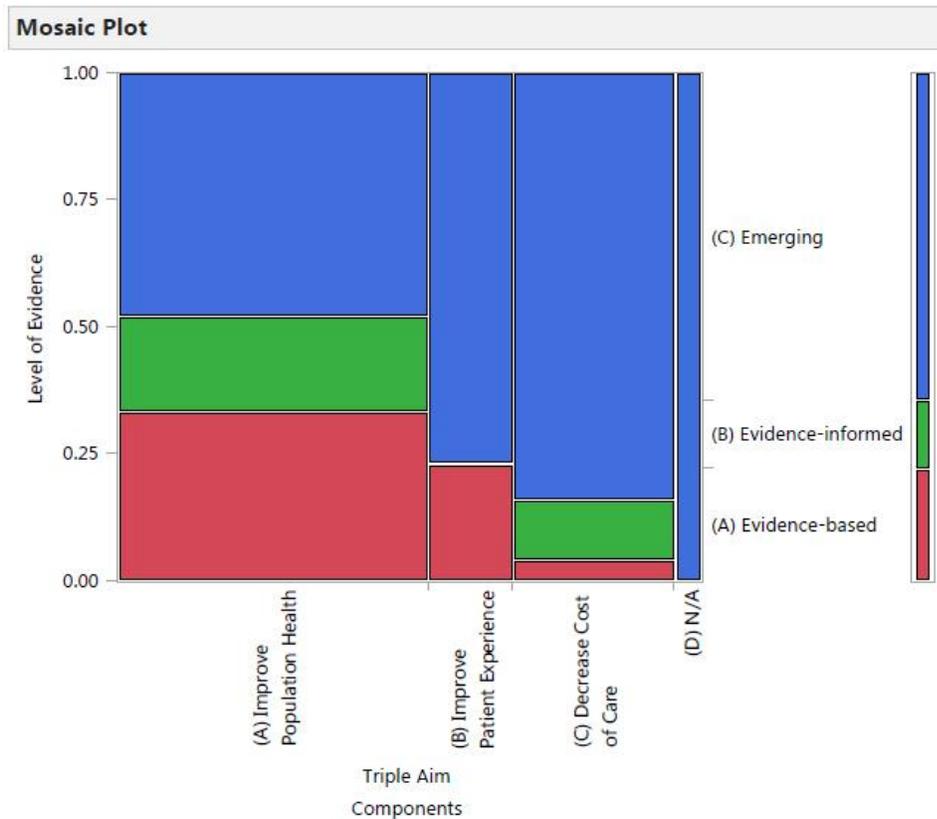
Investment Level

Together, the top quartile of technology companies averaged more than $46 million in investment funding, while the bottom quartile of companies raised less than $20 million on average (Figure 5). The median amount raised by the companies in this review was $30 million. There is no correlation between increasing *Level of Evidence* and *Investment Level* (F-ratio = 0.32, p > 0.05). The top-funded company in our review secured over $160 million in investment funding at the time of this review.

Figure 5. Level of Investment Funding in Technologies
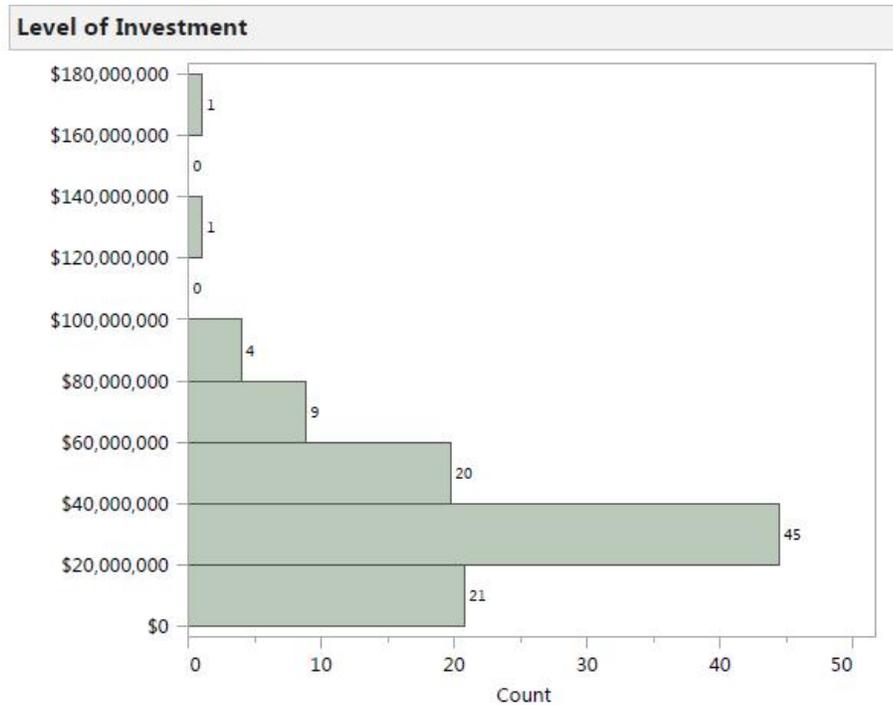
Technology Type

The most common *Technology Types* in this review (Figure 6) are Hospital/Clinic Administration (21 of 87, or 24 percent), Devices (17 of 87, or 20 percent), and Enhanced Patient/Consumer Engagement (13 of 87, or 15 percent).

Figure 6. Number of Technologies by Type
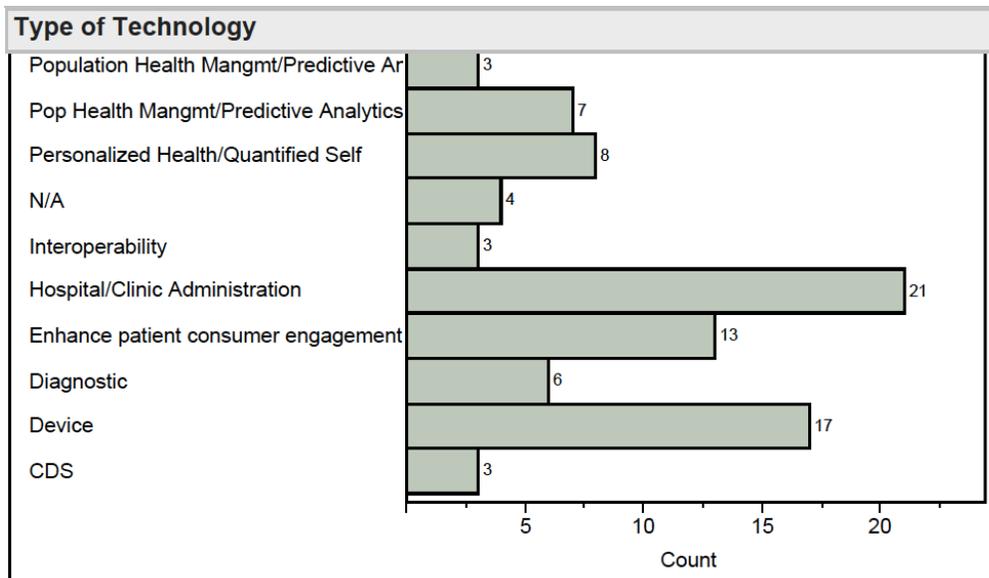
End User

The most frequent primary *End User* type for each technology reviewed (Figure 7) is Providers (52 of 87, or 60 percent), followed by Patients (27 of 87, or 31 percent), and finally Payers (9 of 87, or 11 percent). Technologies for all three *End User* types focus on Improving Population Health as the most common *Triple Aim Component* (Payers: 5 of 9, or 56 percent; Providers: 28 of 52, or 54 percent; and Patients: 15 of 27, or 56 percent). All three technologies that primarily provide Clinical Decision Support and all four technologies performing Remote Patient Monitoring have a primary focus on Providers. All eight technologies that support Personalized Health/Quantified Self have a primary focus on Patients. Provider-focused technologies with an Emerging *Level of Evidence* and an emphasis on Decreasing Cost of Care are the most common cluster (n=18) and are represented by red stars in Figure 8.

Figure 7. Number of Technologies by Type of End User
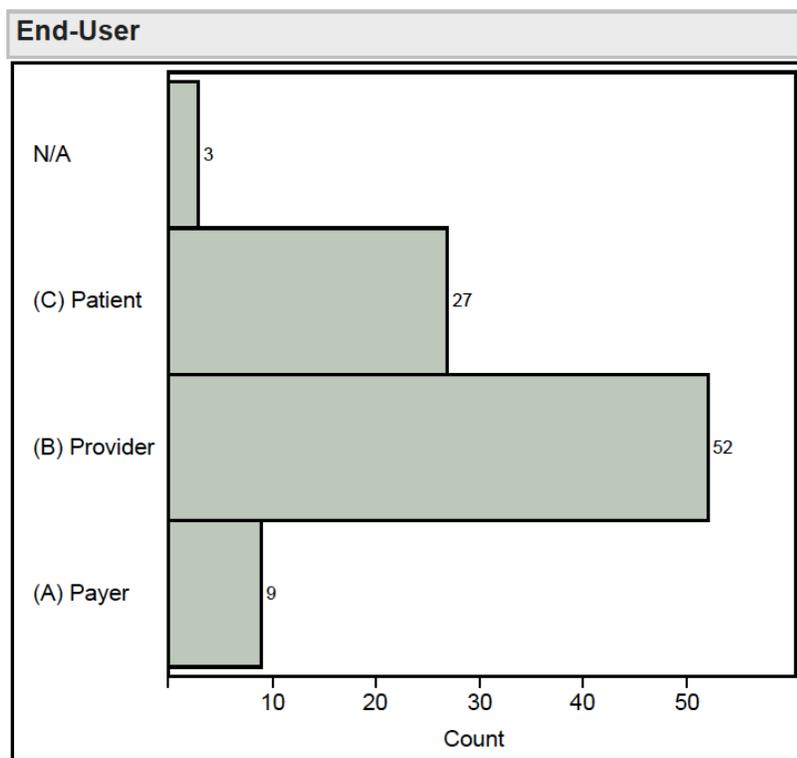
Figure 8. Scatterplot of Technologies by Three Evaluation Criteria (Triple Aim Component, Level of Evidence, End User)
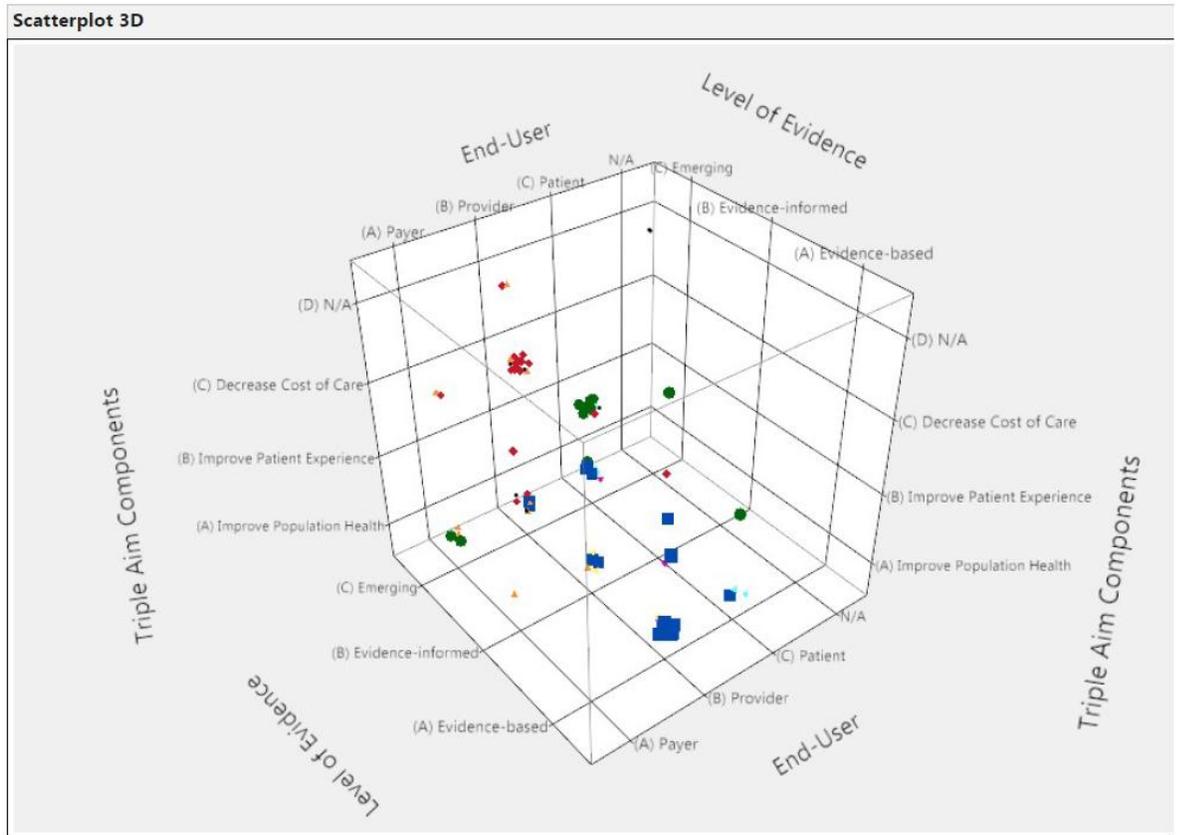
Discussion

This preliminary implementation of the Digital Health Selection Framework identifies a differential distribution among the reviewed technologies based on five criteria: *Triple Aim Component*, *Level of Evidence*, *Investment Level*, *Technology Type*, and *End User*.

Triple Aim Component

The most striking finding of the DHSF is that the vast majority of digital health companies do not simultaneously emphasize achievement of all three *Triple Aim Components*. This limited emphasis on the Triple Aim may reflect a lack of awareness or perceived value of the entire Triple Aim for health technology entrepreneurs. This finding may also indicate a market in transition from technology products that currently serve dominant fee-for-service, volume-driven health care organizations toward technologies that serve value-driven delivery and reimbursement models in the future.

Consumers seeking technologies that support the Triple Aim most commonly start their selection process with Remote Patient Monitoring, Hospital/Clinic Administration, and Enhanced Patient/Consumer Engagement technologies.

Level of Evidence

Investment decisions for digital health appear to be made with little evidence to support a particular technology's achievement of the Triple Aim. Some *Technology Types*, such as those focused on Interoperability or Telemedicine/Teleconsultation, do not have a single example of an Evidence-based offering.

Technologies that are the most Evidence-based tend to focus on Providers. This finding is aligned with our experience with hospitals and physician groups having a high evidentiary threshold for making purchasing decisions. However, despite this finding, even among the so-called "Provider-focused" technologies, the *Level of Evidence* is still quite low. The evidence gap suggests that purchasing decisions are made based on either 1) perceived ability to achieve one or more *Triple Aim Component* and/or 2) criteria independent of the Triple Aim.

Investment Level

Investment in digital health appears to be independent of the *Level of Evidence*, *Technology Type*, or *End User* for whom the technology is being developed. With no significant association between *Investment Level* and *Level of Evidence*, these data appear to contradict the common practice among entrepreneurs to prioritize setting up research pilots to create evidence for their technology. For example, the website for one of the top-funded startups in our review has no peer-reviewed evidence to support its claims that its technology achieves all three *Triple Aim Components*. Yet, this company recently had one of the most newsworthy commercial successes in the history of digital health by completing an initial public offering (IPO).[16] *Investment Level* is likely to depend on other criteria beyond those reviewed in this iteration of the DHSF, such as the reimbursement model that supports the purchase of the technology.

Technology Type

Reimbursement mechanisms appear to be associated with particular *Technology Types*. Our analysis suggests that selection of a particular *Technology Type* is aligned with fee-for-service-based reimbursement for two reasons: 1) the high prevalence of procedure- or visit-based technology (i.e., Devices), and 2) the low prevalence of outcomes-driven technology (i.e., Population Health Management and Telehealth).

End User

In addition to the implications for reimbursement, *Technology Type* sheds light on digital health trends for specific *End Users*. Based on this analysis, there may be unmet needs for technologies focused on all three *End User* types. Most technologies targeted toward Patients focus on trying to improve individual health outcomes. Very few focus on Decreasing the Costs of Care, which may be an opportunity for technology developers to create innovative applications to make consumers more fiscally informed about their health care decisions. Technologies focused on Payers and Providers are more oriented toward costs and outcomes, but suffer from a major lack of emphasis on Improving Patient Experience.

Limitations

This preliminary approach to developing a framework for digital health technology selection has several limitations. First, the review suffers from an availability bias because we exclusively used the Startup Health Insights database. Additionally, the generalizability of this review is limited because we performed a static assessment, which risks becoming outdated in the rapidly evolving startup landscape. Another limitation is the narrow methodology for determining the *Level of Evidence* for each technology; our approach relied on the data reported by each company's website, which may be biased and/or incomplete. Finally, our approach is underpowered to confidently identify the trends to be statistically significant. Consequently, further research is needed to confirm these trends as well as to validate that the DHSF provides value to Patients, Providers, and Payers.

Future Use of the DHSF

Despite its limitations, the Digital Health Selection Framework may have potential use beyond its current application in this analysis. It may be useful to explore other inclusion criteria for the DHSF such as cost to purchase, usability, contribution to care coordination, or emphasis on vulnerable populations. It may also be interesting to look beyond the top 100 funded startups and even consider the inverse analysis by applying the DHSF to the bottom 100 funded startups.

With multiple trends suggesting a failure by developers to address market demand for Evidence-based technology that achieves the Triple Aim, future work is needed to confirm and characterize if there is an ongoing market failure, its causes, and ways in which it can be remedied. Particular attention can be paid to the role of 1) externalization of value to public Payers like Medicare and Medicaid, 2) reestablishing market equilibrium by aligning technology reimbursement with consumers' demand rather than grant programs' priorities, 3) public and private investment to support technology development as the market failure is resolved, and 4) further exploration to identify how to eliminate market inefficiencies.

With recent efforts by the Federation of Medical Boards and the Food and Drug Administration to standardize adoption of digital health technology, there will likely be need and support for approaches to digital health technology selection such as the DHSF.[17,18]

Conclusion

We adapted an algorithm from the computer-science literature into a reproducible process for selecting digital health technology with the greatest value to health systems working to achieve the Triple Aim. The Digital Health Selection Framework (DHSF) we developed uses five criteria for evaluation of such technologies: *Triple Aim Component, Level of Evidence*, *Investment Level*, *Technology Type*, and *End User*. Instead of the current varied, descriptive approaches to technology procurement, IHI developed a comparative, analytic process that allows for discrimination between available technologies on the basis of multiple inclusion criteria. The gaps identified in this analysis offer a glimpse into the unique design challenges and opportunities for entrepreneurs, investors, and other innovators to anticipate market demand for creating technology that will more comprehensively achieve the Triple Aim.

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