Crowdsourcing Applications for Public Health

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Abstract: Crowdsourcing is an online, distributed, problem-solving, and production model that uses the collective intelligence of networked communities for specific purposes. Although its use has benefited many sectors of society, it has yet to be fully realized as a method for improving public health. This paper defines the core components of crowdsourcing and proposes a framework for understanding the potential utility of crowdsourcing in the domain of public health. Four discrete crowdsourcing approaches are described (knowledge discovery and management; distributed human intelligence tasking; broadcast search; and peer-vetted creative production types) and a number of potential applications for crowdsourcing for public health science and practice are enumerated.

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Introduction

As Internet penetration and mobile technology use increases in the U.S. and abroad,[1,2] new opportunities have emerged to take advantage of these technological capabilities to improve public health. Examples include an array of mobile apps to help users track diet and exercise,[3,4] tools to aid smoking cessation,[5,6] websites to prevent binge drinking among college students,[7] mobile apps for pain management,[8] and many others.[9,10] These examples largely use technologies for individual-level health promotion to disseminate health information and messages, deliver a theory-based behavior change program, allow individuals to keep health diaries, or connect individuals with one another for support.

Another class of technological engagement at the population level, crowdsourcing, appears to be underutilized by many public health programs. Crowdsourcing is an online, distributed problem-solving and production model that leverages the collective intelligence of online communities for specific purposes.[11–13] Crowdsourcing can help strengthen the connections among organizations, communities, and populations by facilitating active and collaborative problem solving. In this paper, the crowdsourcing model and its suitability to solve public health problems is explored, and a novel framework to view public health challenges through the lens of collective intelligence is presented.

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Crowdsourcing

In crowdsourcing, an organization communicates a problem or challenge to participants in an online community. Members of this community then provide solutions to the problem, which the crowdsourcing organization processes and consolidates into a unified product. Crowdsourcing is often a highly structured process from the organization's side, drawing on the creativity and intelligence of an online community in an open, but controlled, way. It is a blend of top–down, traditional project management with bottom–up, open innovation principles.[11] This approach has much in common with community engagement and community-based participatory research approaches in that the core of the endeavor is a strong belief that community members can provide solutions to complicated problems that may perplex scientific experts.[14] One major benefit of crowdsourcing is that the solutions are often highly relevant to the intended audience because members of the audience are directly involved in ideation and proposed solutions.[15]

Many people are now familiar with user-generated advertising contests, such as Doritos' Crash the Super Bowl contest, which are examples of crowdsourcing. Frito-Lay launched the Doritos Crash the Super Bowl campaign in 2006 ahead of the February 2007 Super Bowl football championship broadcast. Doritos issues "an open call to its online community to produce 30-second commercial spots featuring the Doritos brand tortilla chips," and individuals in the online community submit their videos to an online gallery, where they are scored in a contest by the public.[16] The winning ads chosen by the

public are aired during expensive, coveted commercial spots during the Super Bowl broadcast and the creators of the ads receive cash prizes from Doritos. The crowdsourced ads are consistently rated in the five best Super Bowl ads according to *USA Today*'s Ad Meter rankings.[17]

Crowdsourcing is driven by principles of open and user innovation, collective intelligence, the wisdom of crowds, and marginality in problem solving. Open innovation and user innovation approaches allow organizations to develop novel products and services faster and better by bringing outsiders, everyday users, and consumers into the research and development process.[18] By breaking down internal silos and relaxing constraints, such as intellectual property rights, organizations can develop co-creative arrangements with lead users, who are often the ones modifying products on their own and pioneering new markets.[18,19]

Collective intelligence refers to the scaled-up capacity of large groups, and the network structure of the Internet helps to foster his kind of large-scale interaction.[20–22] Massive online collaborations, such as the creation and maintenance of the online encyclopedia Wikipedia with its 19 million articles in 270 languages,[23] are examples of Internet-based collective intelligence that generate a wealth of resources better and faster than individual experts.[24] Whereas collective intelligence speaks to scale as a factor in intelligent group performance, the wisdom of crowds speaks to the cognitive diversity and group dynamics enabled by that scale. The wisdom of crowds principle suggests that, in some situations, groups of individuals in the aggregate may solve problems better than individual experts or panels of experts negotiating solutions.[25] The wisdom of crowds specifically concerns problem solving and whether the mean or median of a collection of individual solutions might be more accurate in some situations than individual expert solutions or negotiated single solutions from groups of people, as Surowiecki explained through a variety of historical case studies in his book, *The Wisdom of Crowds*.[25] Both collective intelligence and the wisdom of crowds are connected to robust programs of related research on the science of swarms, stigmergic collaboration, and complexity in systems across a diverse array of disciplines.[26–28]

Marginality is related to diversity in problem solving,[29] suggesting that individuals with different experiences and subject positions bring to a problem-solving environment different cognitive heuristics and may find better success solving problems from positions "on the margin." Technical marginality refers to the distance between a solver's area of technical expertise and the focal area of a problem, meaning that a botanist might solve a difficult chemical problem better than a chemist. Social marginality refers to the social distance of solvers from the mainstream of an industry or discipline, meaning that women, who are typically on the margins of the corporate research and development (R&D) establishment,[30,31] might perform better than men. In a study of InnoCentive, a crowdsourced scientific R&D company, Jeppesen and Lakhani[32] found that the provision of a winning solution to a scientific problem was related to one's technical and social marginality. Site marginality is defined as spatial distance from a corporate headquarters, and rank marginality is defined as having a lower position in the corporate hierarchy. In a study of a multi-office corporation, Villarroel and Reis[33] also found evidence of site and rank marginality as having a positive impact in distributed problem solving. All of these instances of marginality indicate that "outsiders" can often outperform "insiders" in problem-solving environments, and broadcasting or distributing a problem through the network of the Internet may do well to reach these marginal solvers.

The Crowdsourcing Continuum

Crowdsourcing can be conceived as part of a landscape populated by other participatory cultural phenomena, such as posting user-generated videos to YouTube, editing collaborative encyclopedia entries at Wikipedia, blogging, posting content on social networks, and many creative iterations of fan culture.[34] The clear distinction between crowdsourcing and these other phenomena, however, is the blend of top-down hierarchical management of a problem-solving domain and the bottom-up, open solving process of an online community (Figure 1).[35]

Within crowdsourcing, too, there is a continuum of active user participation, from minimal, convenient contributions from individuals to significant and intense contributions of creative effort and analysis. On one extreme, crowdsourcing applications that require minimal participation from an online community might involve the user performing very small amounts of work—microtasks—conveniently via short message service (SMS) text messaging in order to earn small amounts of money.[36] The user is presented with simple tasks, such as translating a sentence from a company's brochure into another language or taking a short marketing survey, and they perform these tasks in spare moments on their smartphones. On the other extreme, crowdsourcing applications that require intense participation might include design contests where individuals come up with complete concepts, 3D architectural renderings, and entire computer-aided design (CAD) files and specifications for fabricating custom vehicles.[37,38]

Some instances involving big data extracted or mined from the masses or from patterns of user behavior on the Internet or through mobile devices may seem like

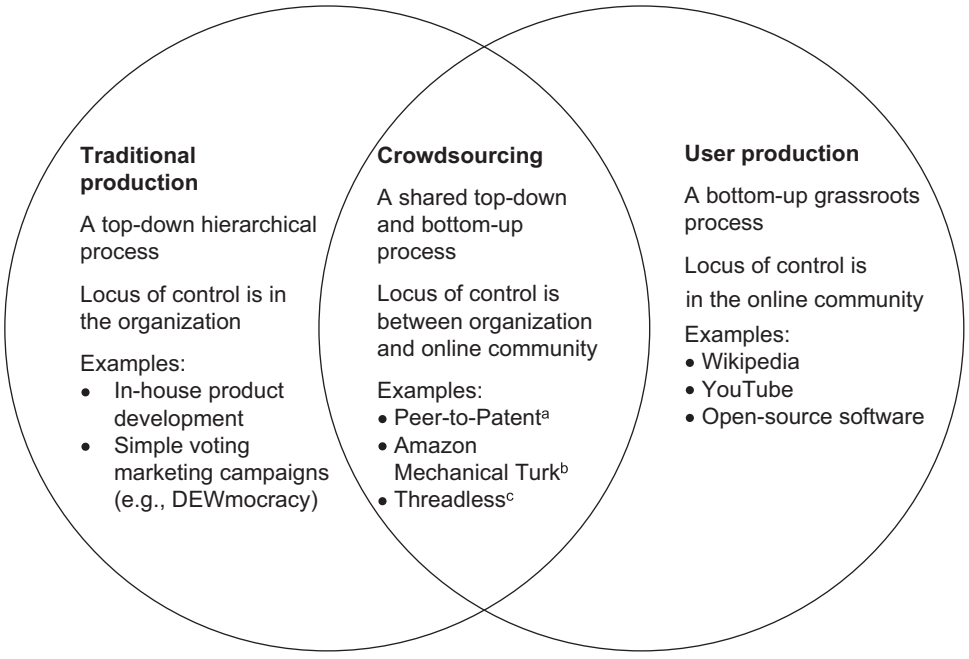

Figure 1. Crowdsourcing as a blend of traditional, top-down production and bottom-up user production

[a]Peer-to-Patent, at PeertoPatent.org, is a project of the U.S. Patent and Trademark Office that mobilizes an online community to find evidence of whether a technology presented in a patent application is novel or if there has already been a similar technology that has been invented by someone else

[b]Amazon Mechanical Turk, at MTurk.com, is a platform operated by Amazon.com that allows organizations to commission small work tasks (microtasks) from an online community for relatively small financial incentives

[c]Threadless, at Threadless.com, is a Chicago-based clothing company that uses an online community to design and select the graphic designs for T-shirts and other products through an ongoing online design contest. Winning designs, selected by peers, are awarded a cash prize, printed as T-shirts, and sold back to the online community on the company's website

crowdsourcing, but these are considered instances of passive data collection and analysis rather than crowdsourcing. To explain this distinction between the "minimal contribution" far end of the crowdsourcing continuum and passive data analysis that falls outside the domain of crowdsourcing, let us consider the case of Google Flu Trends. Typically, the CDC "relies on outpatient reporting and virologic test results supplied by laboratories nationwide" to detect flu outbreaks and this "system confirms outbreaks within about 2 weeks after they begin."[39] Google Flu Trends offers a faster alternative for predicting flu outbreaks by mapping flu-related search trends as they occur. Although the predictive capabilities of Google Flu Trends are not perfect, it does correlate well with actual flu outbreaks and holds much promise as a disease surveillance tool for public health organizations.[40] With Google Flu Trends, the data crumbs that users leave behind in their day-to-day online search behavior are collected and used to model outbreaks. Users, however, are largely unaware of this activity and they do not actively contribute their intellect, creativity, or time to Google Flu Trends. This is an example of data-driven surveillance accelerated by increasingly sophisticated and ubiquitous data-mining tools and clever analytical algorithms. However, because of its lack of active user participation, Google Flu Trends would not count as crowdsourcing by the definition presented here.

In contrast, the U.S. Geological Survey's (USGS's) "Did You Feel It?" earthquake mapping application can be considered crowdsourcing because it demands active user participation. Known formally as the Community Internet Intensity Map, "Did You Feel It?" is a website for citizens to register if they felt the tremors of a recent earthquake, where they live, and the approximate magnitude of the earthquake based on a scale in layman's language provided on the website. In conjunction with automated reports from seismic sensors located around the world, these user-provided reports provide a faster, more complete, and more nuanced portrait of an earthquake's impact, allowing the USGS to mobilize disaster relief within minutes to targeted areas.[41,42] Both Google Flu Trends and "Did You Feel It?" are tremendously useful and are exemplars of a new era of informatics and "big data" in the public health and emergency response professions, but "Did You Feel It?" is a form of crowdsourcing, whereas Google Flu Trends is not.

A Framework for Crowdsourcing for Public Health

Not all problems benefit from collective intelligence and can be crowdsourced. Synthesizing several case studies, Brabham[43] describes a four-type typology for understanding the kinds of problems best suited for crowdsourcing. These crowdsourcing types are: the Knowledge Discovery and Management approach, the Distributed Human Intelligence Tasking approach, the Broadcast Search approach, and the Peer-Vetted Creative Production approach (Table 1). To illustrate the potential for crowdsourcing in public health contexts, the remainder

Table 1. A typology of crowdsourcing problem types for public health[43]

Type	How it works	Kinds of problems	Current and potential uses in public health
Knowledge Discovery and Management	Organization tasks crowd with finding and collecting information into a common location and format	Ideal for information management problems involving information gathering, organization, and reporting, such as the creation of collective resources	Identifying food deserts by gathering user-reported grocery store locations on a map; reporting injury data on playgrounds and dangerous intersections; finding tobacco retailers in states without retailer licensing or conducting a "Product Watch" to report emerging tobacco products, such as dissolvables or e-cigarettes; identifying accessible scarce public health resources at the community level, such as pandemic influenza vaccine; tracking and mapping illness trends and clusters, e.g., using GermTrax.com; participatory sensing of particulate matter levels, e.g., the CitiSense platform[44]; gathering information on the use and condition of parks and bike trails
Distributed Human Intelligence Tasking	Organization tasks crowd with analyzing large amounts of information	Ideal for information management problems involving large-scale data analysis where human intelligence is more efficient or effective than computer analysis	Language translation for health campaign brochures and websites; making data entry, cataloguing, and organizing information more efficient and cost effective for health organizations; behavioral modeling for weight loss factors; disease and behavior change data registries, e.g., National Weight Control Registry[45]
Broadcast Search	Organization tasks crowd with solving empirical problems	Ideal for ideation problems with empirically provable solutions, such as scientific problems	Identifying novel solutions to sanitation in the developing world, e.g., the Bill and Melinda Gates Foundation's Reinvent the Toilet Challenge[46]; issuing challenge briefs for vaccines to prevent emerging diseases; designing medication bottles to prevent unintentional overdose; developing new designs for cooking and heating stoves in developing nations that produce little or no particulate matter; developing algorithms for predicting disease outbreaks and remedial measures
Peer-Vetted Creative Production	Organization tasks crowd with creating and selecting creative ideas	Ideal for ideation problems where solutions are matters of taste or market support, such as design or aesthetic problems	Getting community input on where to locate a park or community recreation center; adding bike lanes to city streets to promote active transit; developing social marketing campaign themes or target messages; developing menus and policies for school lunch programs; designing and determining optimal siting for community gardens and farmer's markets

of this paper is devoted to a closer examination of four different problem types in public health and their suitability to be tackled through crowdsourcing applications described in Brabham's[43] typology.

A Knowledge Discovery and Management Problem

The Knowledge Discovery and Management (KDM) approach to crowdsourcing is ideal for information management problems requiring information gathering, organization, or reporting, such as the creation of collective resources. Organizations employ the KDM approach when the problem they face involves knowing that information exists outside of the organization in scattered locations and needing that information discovered and brought together in specific formats in a single location. KDM involves mobilizing an online community to perform this information gathering and reporting function. Structurally, the KDM approach to crowdsourcing is the most like "commons-based peer production"[24] that takes place at Wikipedia, except the crucial difference is that "no one at Wikipedia…issues specific tasks to the online community there and manages the creation of articles."[43] Although the community of Wikipedians has developed a sophisticated set of protocols for self-governance from the bottom–up,

there is no top–down managerial hierarchy driving production at Wikipedia, no organization at the top directing work like there is in KDM crowdsourcing endeavors. Brabham[35] examines in detail the distinction between crowdsourcing and similar phenomena, such as Wikipedia, open-source software, and simple marketing contests.

A notable example of KDM is SeeClickFix.com. People can access the SeeClickFix website on their computers or smartphones and "post concerns about problems from potholes to noisy neighbors to broken stoplights" in their neighborhoods.[47] City administrators can use the information to better allocate resources to address minor problems in neighborhoods before they worsen. Journalists also use SeeClickFix as a starting point for reporting on city crime patterns, deteriorating facilities, and government responsiveness. Citizens enjoy a convenient reporting mechanism that does not require them to look up specific phone numbers and email addresses for various municipal departments to report a variety of issues they may encounter in the city. From a public health standpoint, citizens using SeeClickFix might report traffic hazards, garbage, sanitation problems, or surface water contamination. Other public health initiatives in this vein include neighborhood asset mapping, mobilizing volunteers in a community to report environmental determinants of chronic disease risk factors,[48] as well as tasking citizens with locating, photographing, and mapping emergency automated defibrillators with smartphones in the MyHeartMap Challenge.[49,50]

A Distributed Human Intelligence Tasking Problem

Sometimes called "human computation,"[51] the Distributed Human Intelligence Tasking (DHIT) is ideal for information management problems involving large-scale data analysis where human intelligence is more effective or efficient than computer analysis. Organizations employ the DHIT approach when the problem they face involves tackling a large corpus of information that computers cannot process in an automated way. These organizations then decompose the voluminous data into tiny fragments and distribute the information to an online community to process bit by bit. By carving the data set into small, simple portions, a crowd of individuals can handle the data set more efficiently than a computer can, depending on the kinds of data there are to be processed.

A notable example of the DHIT form of crowdsourcing is Amazon Mechanical Turk. Organizations can post large data sets to the MechanicalTurk.com website for analysis. Individuals in the online community at Mechanical Turk, called "Turkers," then make small amounts of money to perform data analysis tasks. Amazon CEO Jeff Bezos calls this arrangement "artificial artificial intelligence,"[52] because humans integrate seamlessly with computers to create a composite sense of artificial intelligence.[53] These tasks include, for example, a company needing a database of contact information for restaurants checked for accuracy, an organization requiring website content translated into a different language, or a company needing large sets of images labeled and categorized.

Kirchner et al.[54] and Tacelosky and colleagues[55] utilized a custom Mechanical Turk interface for analyzing thousands of mobile phone photographs of retail point-of-sale tobacco marketing. Over the course of one typical implementation, 299 Turkers completed more than 23,000 tasks at a total cost of $2500 in less than 24 hours. Results of the crowdsourced photo-only assessments had an excellent level of correspondence to the traditional field survey data, demonstrating that mobile phone photographs have tremendous potential as a medium for distributed, sustainable remote sensing of health-related data present in the natural environment. Further, the Kirchner et al.[54] and Tacelosky and colleagues[55] data provide a photo archive that can be integrated into a longitudinal record and mined for new information in perpetuity. Other health-related applications of this DHIT method using mobile phone photographs could include surveillance of damage to roads and bridges, hazardous waste sites, as well as the presence and marketing of other hazardous products, such as high-calorie foods and alcohol.

Modeling human behavior in an automated way with increasingly large and complex data sets is common. However, "the task of choosing which potentially predictive variables to study is largely a qualitative task that requires substantial domain expertise."[56] In a pilot study, Bongard et al.[56] developed a way to crowdsource the identification of these variables, and one of their test cases involved predicting users' BMI. To use this system, a user would visit the study website and enter his or her height and weight, which generated the user's BMI. Alongside the user's BMI were displayed two additional numbers, the average BMI for the 10 users just below the user and the average BMI for the 10 users just above the user. The user then answered a series of questions about his or her behaviors and lifestyle, such as *How many, if any, of your parents are obese?* and *How many times do you cook dinner in an average week?*[56] Users also could propose new questions for future users to answer, thus creating a new variable for which to gather data and model. By answering the behavioral questions and proposing new questions for future users to answer, users generated new variables and modeled them against

BMI. As user input grows, so too does the data set, and the predictive power of certain behavioral variables on BMI comes into focus.

A Broadcast Search Problem

Sometimes called "innovation contests,"[57] the Broadcast Search (BS) approach to crowdsourcing is ideal for ideation problems with empirically provable solutions, such as scientific problems. Organizations employ the BS approach when the problem they face involves finding the specific information or unique insight that lies outside the organization and bringing it to bear on a specific problem. BS involves promoting this kind of challenge, with all of its specific parameters, to an online community in the hopes that at least one person in the community may know the answer. The BS approach can be understood as trying to locate a needle in a haystack or casting a wide net in the hopes to catching a rare and elusive fish.

A notable example of the BS approach to crowdsourcing is InnoCentive.com. People can access the InnoCentive website and read challenge briefs posted by scientific R&D companies, such as Procter & Gamble, Boeing, and DuPont. These briefs outline specific chemical, mathematical, engineering, or other problems and ask individuals in the online community to attempt a solution. Those who come up with solutions submit them on the website, and correct solutions earn the solver a cash reward in exchange for the company receiving the intellectual property rights to the solution. NASA also has used InnoCentive with some success, asking the online community at InnoCentive to "devise a formula for predicting solar flares," which was subsequently solved by a retired radio frequency engineer from New Hampshire,[58] suggesting that the application of the BS approach extends beyond for-profit R&D contexts. BS applications also may take the form of games, as in the notable and successful case of Foldit, a project that allows users to make a game of solving puzzles of protein folding designs to find cures for diseases such as HIV.[59]

A Peer-Vetted Creative Production Problem

The Peer-Vetted Creative Production (PVCP) approach to crowdsourcing is ideal for ideation problems where solutions are matters of user preference or market support, such as design, aesthetic, or policy problems. Organizations employ the PVCP approach when the problem they face involves generating new creative ideas for solving a given problem that affects external stakeholders, and the creativity, talent, and information needed to solve the problem exists outside of the organization, among the external stakeholders. PVCP involves empowering an online community to both generate ideas and then select which ideas are best. In this arrangement, the crowdsourcing organization facilitates a collaborative design process that takes place within the online community.

A notable example of the PVCP approach to crowdsourcing is Threadless.com. People can access the Threadless website to submit t-shirt designs or vote on the designs of others. At the end of a 1-week voting period, the designs that get the highest average votes are printed and sold as T-shirts on the Threadless website.[60] To answer the challenge of how to create new, original designer T-shirts that sell, Threadless collapsed the creative ideation process into the market research process by giving its online community the ability to create and to vet T-shirt designs, all before taking on the risk and cost associated with printing the T-shirt in large runs.

The PVCP crowdsourcing approach also works well as an online, public participation tool for policymaking and urban planning. The Next Stop Design project, which employed a PVCP crowdsourcing approach to solicit designs for bus stop shelters and ideas for bus routes in the Utah Transit Authority's public transportation system, demonstrated the applicability of crowdsourcing in the design of public space.[61] Crowdsourcing for urban planning also has been successfully tested in Massachusetts' inTeractive Somerville transportation planning project[62] and provided as a "crowdsourced placemaking" service by urban development companies.[63,64] Using this form of crowdsourcing for the design of urban space to keep citizens safe or encourage healthy behaviors, such as walking or biking, seems a natural fit for public health applications.

Limitations and Conclusion

Public health practitioners faced with information management problems or ideation problems may find solutions by turning outward toward the crowd, welcoming creative input and inexpensive or free labor from online communities. We argue that crowdsourcing offers a number of fruitful paths toward improving health behaviors through citizen involvement online. A methodologic framework that includes four crowdsourcing types—the Knowledge Discovery and Management approach, the Distributed Human Intelligence Tasking approach, the Broadcast Search approach, and the Peer-Vetted Creative Production approach—is presented, each addressing a distinct problem environment. This framework is intended to help researchers navigate the range of emerging crowdsourcing technologies and identify relevant resources. We also believe the framework provides a

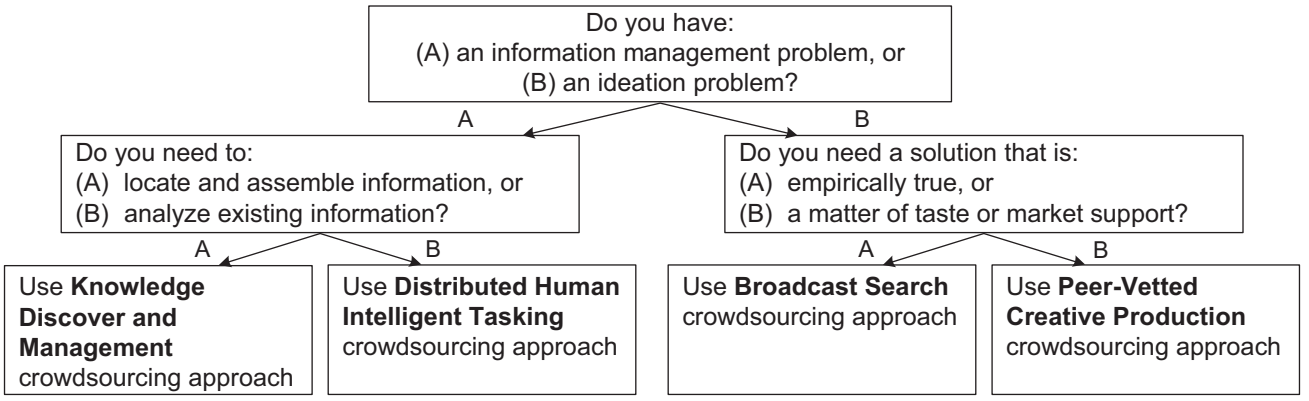

Figure 2. Decision tree for determining suitable crowdsourcing type based on problem

useful tool for introducing those unfamiliar with crowdsourcing to the problem domains it can address.

Once a problem has been defined and solution parameters are known, a public health practitioner or organization may pose a few simple questions to home in on the appropriate crowdsourcing approach (Figure 2). The first determination is whether a problem is an information management problem or an ideation problem. Given an information management problem, one must then decide whether the information needs to be located and assembled, leading to a KDM crowdsourcing approach, or whether the information that is already in hand needs to be analyzed, leading to a DHIT crowdsourcing approach. Given an ideation problem, one must decide whether the solution will be empirically provable, leading to a BS crowdsourcing approach, or a matter of taste or market support, leading to a PVCP crowdsourcing approach.

Once a crowdsourcing approach is chosen, practitioners and organizations should implement a crowdsourcing application with best practices in mind, including understanding the composition of a crowd, the motivations for participation and incentive structures, and legal and ethical implications for crowdsourcing.[43,65,66]

Crowdsourcing is by no means a panacea. Crowdsourcing has been criticized as a threat to and disregard of professional expertise,[67] an exploitation of creative labor,[68] and an exclusionary method that leaves the digital "have-nots" in the digital divide out of the picture.[11] In its most effective applications, crowdsourcing is a supplement to traditional, on-the-ground, face-to-face methods for participation, not a replacement.[15] A public health campaign should not deploy a crowdsourcing application as a sole method for gathering public input on a problem, but rather it should view crowdsourcing as just another tool in the growing toolbox for improving public health with technology. However, coupled with more traditional methods, crowdsourcing can bring new voices into the dialogue about public health, especially younger audiences and those who might otherwise prefer to stay on the margins if not for a convenient way to participate via Internet or mobile technology.

New media technology fosters a convergence of data, citizens, health professionals, and policymakers that enables new tools and processes to improve public health. Crowdsourcing provides a flexible methodologic framework within which organizations can shepherd citizen efforts to produce goods and solve problems. Future health-related crowdsourcing endeavors will no doubt capitalize on a rapid proliferation of "smart" mobile technologies, even in developing nations,[69] accelerating health-related innovations requiring real-time user-generated data or emergency response. At the same time, growing archives of user-submitted data and social networks built around health and healthy behaviors[45,70,71] offer more building blocks with which citizens and organizations can collaborate and thereby construct new ways to improve public health.

Future research might explore the effectiveness of public health campaigns using crowdsourcing, interviewing users as to their expectations and experiences interacting in such a way online. Future research also would benefit practice by refining best practices, ethical frameworks, and tactical approaches for deploying crowdsourcing applications.

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