How can crowdsourcing help tackle the COVID-19 pandemic? An explorative overview of innovative collaborative practices

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The COVID-19 pandemic has caused unprecedented public health and economic crises. As a response to face the current emergency, science and innovation communities are realizing a fundamental contribution to tackle the crisis. During the past few months, we have witnessed an impressive number of initiatives to encourage networking opportunities, to foster interactions between the different stakeholders involved (health care, industry, governments, academics, ordinary people), and to develop innovative solutions and collaborative infrastructures in support of the health sector. Adopting an open and collaborative approach and joining forces is essential in the fight against the COVID-19 crisis. Also, the involvement of crowds as innovation partners can be of great support. Therefore, our work aims to review and classify those initiatives, based on the crowdsourcing model, that have been put into place to face the emergency generated by the novel coronavirus pandemic. We illustrate the 16 crowdsourcing initiatives devoted to the SARS-CoV-2 outbreak that we identified, detailing their development and implementation. Then, we propose a classification of them, along two dimensions: type of crowdsourcing configuration and kind of tasks, being able to find a relationship between these two aspects. Evidence from the analyzed projects suggests that across disparate domains, crowdsourcing can be an effective strategy in the response to the COVID-19 pandemic. To conclude, we suggest some important implications for innovation best practices and lessons that can be learned for the future: crowdsourcing, harnessing the power of crowds and online communities, can help tackle the COVID-19 pandemic, by providing original, actionable, quick, and low-cost solutions to the challenges of the current health and economic crisis.

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1. Introduction

Over the last few months, the coronavirus disease 2019 (COVID-19) has spread with unprecedented speed and scale, and the outbreak situation is constantly evolving. At the time of this writing, with over 4,000,000 confirmed cases of COVID-19, including almost 300,000 deaths, that have been reported to the World Health Organization (WHO) globally (World Health Organization, 2020), this is one of the largest medical disasters since the Spanish flu pandemic of 1918. The current pandemic has put and is putting a strain on national public systems around the world; also, it is having severe economic repercussions, posing unprecedented business challenges. In this context, as highlighted by Chesbrough (2020), innovation and R&D management will play an important role in the recovery. Moreover, as the results provided by Ahn et al. (2018) suggest, utilizing external knowledge and increasing a high-level openness can be effective approaches in an economic downturn. As a response to face the COVID-19 emergency, science and innovation communities are realizing a fundamental contribution to tackle the crisis. During the past few weeks, we have witnessed an impressive number of initiatives to encourage networking opportunities, to foster interactions between the different stakeholders involved (health-care ecosystem, industry, governments, academics, citizens), and to develop innovative solutions and collaborative infrastructures in support of the health sector. As Chesbrough (2020) states, 'good ideas can come from anywhere, making openness is an imperative in these times of crisis'. We believe that adopting an open and collaborative approach and joining forces is essential in the fight against the COVID-19 crisis since to answer the 'most vexing innovation and research questions' crowds are becoming the partner of choice (Boudreau and Lakhani, 2013). Therefore, this work aims to review and classify those initiatives, based on the crowdsourcing model, that have been put into place to face the emergency generated by the novel coronavirus pandemic. Crowdsourcing is an online, distributed problem-solving and innovative sourcing model, in which members of online communities contribute to carrying out specific tasks. Crowdsourcing has a lot of potential in operationalizing open innovation strategies and despite this field has manly developed in information technology or management and business, it can be a promising tool in health, and in global health in particular (Wazny, 2018). It allows collecting a huge amount of data and information from people all over the world, complementing the traditional data collection. Also,

it is low cost, rapid and it has the potential to accelerate research due to the amount of work that can be concentrated on a single challenge in a short period (Saez-Rodriguez et al., 2016). So, as Wazny and Chan (2018) argued, all these qualities make it especially advantageous in the context of global health, conflict, or humanitarian settings. In recent years, the adoption of crowdsourcing in health has been of scholarly interest and there is much evidence to support the effectiveness and the successful use of crowdsourcing applied to this sector.

The remainder of the paper is organized as follows: in the second section, we briefly review the adoption of crowdsourcing in health, together with the presentation of a framework, build on the ones proposed by Brabham et al. (2014) and Simula and Ahola (2014). In the third, we present the methodology; in the fourth section, we provide an in-depth description and analysis of the crowdsourcing initiatives implemented to deal with the COVID-19 emergency. In the fifth section, we illustrate and discuss the study findings; finally, we conclude illustrating the contributions to both researchers and practitioners in the field of innovation and R&D management and the health field.

2. Theoretical background

The term crowdsourcing was coined for the first time in 2006 by Howe to represent the act of organizations outsourcing their tasks to an undefined and large group of people, but the concept finds its roots in initiatives already in use in past centuries, as the case of the prize established in 1714 by Britain's Parliament in the Longitude Act reported by several authors (Ranard et al., 2014; Créquit et al., 2018; Wazny, 2018). Over the last decades, with the advent of Web 2.0 and the development of digital technologies, it has progressed, as the Internet has greatly reduced the cost of information transfer and the boundaries of participating (Wang et al., 2019). It is now recognized as an efficient and useful tool for innovation and competitiveness with a wide range of applications and it has benefited many sectors of society (Brabham et al., 2014). Novel forms of research that leverage the collective intelligence of different individuals involved through crowdsourcing are emerging successfully in various fields (Nguyen et al., 2019). According to Palacios et al. (2016), for various industries and society in general, it represents a new paradigm that is disrupting or altering the current dominant logic. In the crowdsourcing model, organizations use predominantly advanced internet technologies

to harness the efforts of a virtual crowd to perform specific organizational tasks or problem-solving activities (Saxton et al., 2013), outsourcing tasks to internal (usually firm's employees) or external crowds. Consistent with the open innovation paradigm, crowdsourcing can help the reduction of R&D costs, sharing of the risks of innovation, and it can increase the speed at which new innovative products and services are brought to the market since it allows easier access to a wide variety of skills, know-how, and expertise. As noted by Greco et al. (2016), adopting a 'crowd-based innovation strategy', in which the knowledge input is sourced from a large number of actors, can improve the development and market success of innovations, in particular incremental. Majchrzak and Malhotra (2020) in their book present a series of successful cases showing that crowds can collectively solve complex wicked problems in many different fields. Crowdsourcing can embrace very different configurations, depending on the context and type of task to be performed (Schenk et al., 2019) and the expert literature offers a rich landscape of taxonomies (Geiger et al., 2011; Saxton et al., 2013; Hosseini et al., 2015), typologies (Brabham, 2013; Colombo et al., 2013), and categorizations (Simula and Ahola, 2014). For our purpose, we will rely on two different typologies. The first one is the categorization proposed by Simula and Ahola (2014). The authors identified four possible configurations of innovation crowdsourcing available to firms and organizations, analyzing them from a network perspective: internal crowdsourcing, community crowdsourcing, open crowdsourcing, and crowdsourcing via a broker. In the first configuration, the focal firm is connected to all its employees. The community crowdsourcing presents a densely connected network (many-to-many), and the involved actors are the focal firm and the contributors, preselected on the basis of specific resources or required knowledge. In the open crowdsourcing, the network configuration is star-shaped (one-to-many) and the focal firm is connected to potentially unlimited contributors, without any form of preselection, while in the crowdsourcing via a broker configuration, the focal firm is connected to a broker, which is then connected to potentially unlimited contributors. The second categorization is the one proposed by Brabham et al. (2014) and it is focused on crowdsourcing problem types for public health. The authors distinguish four categories: Knowledge Discovery and Management, Distributed Human Intelligence Tasking, Broadcast search, and Peer-Vetted Creative Production. In the first type, the objective is to find and collect information and it is ideal for problems that involve information gathering, organization, and reporting; in the second type, organizations rely on crowds to analyze a large set of data and amounts of information. So, the Distributed Human Intelligence Tasking is suitable for problems involving large-scale data analysis where the skills of human intelligence are required. The Broadcast Search is used by organizations to find solutions to specific problems (e.g. scientific problems), gathering specific information or innovative strategies to create, develop, or implement empirical solutions. In the last type, organizations submit to the crowd tasks related to the generation and selection of innovative and creative ideas to support marketing or the design process.

Crowdsourcing is increasingly used to improve public health (World Health Organization, 2018) since it offers the possibility to mobilize a large and diverse community through enhanced communication and collaboration (Nguyen et al., 2019) and crowdsourced R&D has demonstrated success in contexts of medical research (Callaghan, 2015). The adaptability and flexibility of crowdsourcing fit with medical and health-care applications; in this field, there are specific applications and tasks for which crowdsourcing proves to be appropriate: data processing, surveying/monitoring, surveillance, and problem-solving (Ranard et al., 2014; Créquit et al., 2018) and the literature reports a plethora of initiatives put into action. Pan et al. (2018) distinguish two distinct types of contests, outcome-oriented contests, and process-oriented contests, whereas Tucker et al. (2019) indicate three types of activity – challenge and innovation contests, hackathons, and online collaboration systems. According to Natalicchio et al. (2017), an innovation challenge consists in an open solicitation to the public promoted by an organization aiming at finding solutions to an innovation problem, in which each member in the crowd self-selects to take part in. This way, innovation contests issue open calls to solicit new ideas or strategies from the public. Many contests have focused on improving health and, given their proven effectiveness, the WHO has also indicated guidelines to provide practical advice on designing, implementing, and evaluating crowdsourcing activities for health (World Health Organization, 2018). The hackathons are short (usually 1–3 days) events that bring together individuals around a common cause; online collaboration systems mean websites or portals that allow individuals to solve micro-tasks, often for a small amount of money as a reward. As shown above, a wide spectrum of initiatives falls under the

crowdsourcing term. Crowdsourcing shows promise as a source of innovative health-care technology solutions (Ko et al., 2015) and it can help answer important health-related research questions (Ranard et al., 2014), improving the quality, cost, and speed of a research project while engaging large segments of the public and creating novel science (Ranard et al., 2014). For all these reasons, we believe that the interest in crowdsourcing initiatives being implemented in the context of the COVID-19 emergency is solid, appropriate, and well-motivated.

3. Methodology

Thanks to its variety of approaches and flexibility, crowdsourcing has been recognized as a useful tool during crises for crisis monitoring, emergency planning, and crisis management, social cohesion, and research (Conrad et al., 2020; Desai et al., 2020). Timely intervention is essential to try to respond effectively to the crisis. We agree with Chesbrough (2020) who states the importance of opening up to mobilizes knowledge from many different places and sources to advance our learning and to accelerate our progress against the disease. Challenging problems might benefit from solutions from others in different places around the world and the use of crowdsourcing for the resolution of some of these problems may speed up the possibility of finding the best solution. The global COVID-19 health emergency 'has spurred an unprecedented response on one side by the biomedical research community aimed at identifying the mechanism of transmission, infection and immune response, epidemic forecasting and treatments for this novel disease' (Desai et al., 2020), on the other by the innovation community to stimulate and disseminate innovative practices in the effort to prevent, mitigate, and ultimately overcome this crisis. Likewise to what was done in the past under similar circumstances, for example, by Conrad et al. (2020) about the development and application of a crowdsourced effort to assist in relief efforts during Hurricane Harvey, this paper details the development and implementation of crowdsourcing projects and initiatives devoted to the SARS-CoV-2 outbreak. Besides the crowdsourcing projects for COVID-19 reported by Desai et al. (2020) with a specific focus on oncology and medicine, we identified 16 crowdsourcing initiatives. In order to find relevant information, we browsed the Web, consulting search engines, databases that collected crowdsourcing projects (e.g. Crowdsourcing Week, 2020), and aggregators of resources related to the current COVID-19 pandemic (e.g. EU-Citizen Science, 2020). We selected the initiatives based on the relevance of the topic, the relevance of the strategic intent, and backing organizations (e.g. well-known intermediary platforms, such as those gathered in the list by Board of Innovation (2020)).

In our classification, we considered the innovation challenges part of the Broadcast Search; furthermore, we took into account hackathons.

4. Crowdsourcing initiatives to face Covid-19 crisis

Challenge and innovation contests have the potential to 'bring together otherwise disparate communities, actively engaging key sectors of the population who may not always be heard' (World Health Organization, 2018). Several of these initiatives have been hosted and facilitated by already existing platforms, as in the following cases.

TopCoder is an online platform that provides crowd-contest services (Boudreau and Lakhani, 2013; Brown, 2017). The *Anti-Coronavirus Hackathon – ideation challenge for social good* is the call to the *TopCoder*'s community about ideas to help people, the governments, or organizations during the time of coronavirus spreading.

Initiated as an internal crowdsourcing pilot program (Rando et al., 2011; Davis et al., 2015), *NASA@work* is now an agency-wide, virtual platform that seeks to increase innovation by promoting collaboration within its community through interactive discussions and presenting challenges to be solved. Starting from April 1, NASA exploited its employee crowdsourcing initiative *NASA@work* to solicit new ideas on ways the agency could respond to the COVID-19 pandemic.

The crowdsourcing platform *Openinnovability* by Enel hosts the *Call4Ideas COVID-19 Challenge*, launched by Marzotto Venture Accelerator and Campus Bio-Medico University of Rome. This call is direct to anyone – individuals or companies – who has an idea to be transformed into an entrepreneurial project or already an innovative project, useful to concretely support the Italian system in the response to the current crisis. The deadline to participate is May 31, 2020. The contest comprises several areas of interest: medical and personal protective equipment, data analysis, telemedicine and home care, diagnostics, therapy and post-therapy, cybersecurity, logistics, smart working, to name a few.

InnoCentive, one of the largest crowdsourcing platforms for innovation problems, has created a pavilion exclusively for coronavirus-related challenges, in which each challenge has a specific

problem area defined for either required solutions or ideas to be submitted. At the moment, there are nine challenges available, eight of which are open and one under evaluation, covering different arguments from theoretical challenge about new technologies to prevent the transmission of coronavirus to ideation challenge about behaviors still not widespread to diminish the transmission of COVID-19.

Similarly, *NineSigma*, another leading crowd-sourcing intermediary (Lopez-Vega et al., 2016) has reserved a section of its platform to the coronavirus outbreak.

Kaggle allows scientists and others to post complex data analysis problems along with monetary rewards for the best solution (Boudreau and Lakhani, 2013; Ranard et al., 2014). In response to the COVID-19 pandemic, on *Kaggle* the *COVID-19 Open Research Data set (CORD-19)* is freely available to the global research community. This resource consists of over 59,000 scientific articles, including over 47,000 full-text articles, about COVID-19, SARS-CoV-2, and related coronaviruses. There is also a call to action for the artificial intelligence experts to develop text and data mining tools that can help the medical community to develop answers and generate new insights to support the ongoing fight against the COVID-19.

Solve is an initiative of the Massachusetts Institute of Technology (MIT) with 'a mission to solve world challenges'. It acts as a marketplace for social impact innovation, using an open innovation method to take a bottoms-up approach to discover relevant and lasting but underestimated innovation challenges. Solve launched a new 'global challenge' around *Health Security & Pandemics* for seeking tech innovations that can slow and track the spread of the emerging outbreak. The program's current application deadline is June 18, 2020.

CoVent-19 Challenge is an open innovation 8-week Grand Challenge in two rounds for engineers, innovators, designers, and makers launched on the GrabCAD Challenges platform on April 1, 2020. It aims to foster the rapid development of an 'innovative, deployable, minimum viable mechanical ventilator for ventilator-dependent patients due to lung lesions related to COVID-19'. The goal is to create CAD assemblies by May 1, 2020 (round one), and functional prototypes with acceptable performance by June 1, 2020 (round two).

Some other initiatives were organized or created from scratch specifically to respond to the challenges generated by the pandemic.

EUvsVirus is a pan-European hackathon organized by the European Commission, in which the participants are involved online to develop prototypes and solutions that can help address issues of technical,

political, and social relevance in the context of the coronavirus crisis. As stated by the organizers, the aim is to collectively develop innovative solutions for 37 challenges in five distinct areas: health & life, business continuity, social & political cohesion, remote working & education, digital finance, and other. The event was held from 24 to 26 April.

The *CODEVID-19 global hackathon* is an open platform where anyone interested can join a team or share feedback and ideas in four problem areas: supporting crisis response, understanding the pandemic, social distancing and isolation, scarcity and the economy. It aims at building useful and effective apps to help carry people through the COVID-19 pandemic. This initiative is currently ongoing.

Crowdfight COVID-19 is an initiative from the scientific community to put all available resources at the service of the fight against COVID-19. The service is targeted to COVID-19 researchers, that can share a wish or a task, explaining their request in a few lines. The request can go from a simple time-intensive task to be performed (e.g. transcribe data), to answering a technical question which is beyond their field of expertise, or to setup a collaboration. Then, another scientist in the community strives to understand this request and realize it.

Beat the Vid is a call for ideas and technological projects, always open, launched by the community of innovation Opinno IO to stimulate a positive impact through innovation in light of the COVID-19 crisis. Challenges embrace different categories: new normal (recovery and normalization of the health-care sector); prevention (prevent future waves of the virus to minimize its impact on health-care facilities); diagnosis (diagnose the virus in a reliable, easy, and remote way); treatment (ensure access to basic means of treatment for all); supply (improve the logistical supply of medical equipment) and monitoring (ensure continuous monitoring of infected patients).

The Italian platform *Idea Sospesa* has been created to gather ideas and concrete solutions, that can be implemented quickly, to help the small real economy to recover, with a specific focus on craftsmanship, transport, trade & small business, self-employed, events, tourism & hospitality. The deadline for contributing ideas was April 25, 2020. Similar initiatives have also been carried out in India (*Ideas for Goa*) and Belgium (*Idées Suspendues*). The implementation mechanism is the same: ideas provided through crowdsourcing are gathered and made available on the website to be voted on and commented by the users. As contributions are submitted, the most popular ideas are published at the top of the list, giving due recognition to the idea provider. Based on the votes received, the top ideas are then

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shared with the society at large, public institutions, government, and potential implementation/support agencies.

As we have seen above, one of the common tasks of crowdsourcing in health is surveillance or monitoring to find and collect information into a common location and format. Initiatives like *COVID Near You, CovidTesting*, and *FluTracking* fall under this category.

COVID Near You is a new website developed by researchers at Harvard Medical School and Boston Children's Hospital which invites the public to report current symptoms in real time, identified only by ZIP code. This allows experts to track specific sites where COVID-19 is spreading or receding and at what rate. *COVID Near You* uses crowdsourced data to visualize maps to help both citizens and public health agencies identify current and potential hotspots for the pandemic.

Open Health Network is making an interactive map of test sites called *CovidTesting*, crowdsourcing a list of COVID-19 testing facilities across the USA.

FluTracking is a surveillance system that leverages the internet and the community spirit to detect and monitor the spread of influence in Australia and New Zealand, and it is now used to track COVID-19.

5. Results and discussion

Starting from the typologies presented in Section 2, we propose a classification of the crowdsourcing initiatives in the context of the COVID-19 pandemic, along two dimensions: type of configuration (internal crowdsourcing, community crowdsourcing, open crowdsourcing, crowdsourcing via a broker) and kind of tasks (knowledge discovery and management, distributed human intelligence tasking, broadcast search, peer-vetted creative production) (Table 1). This choice is motivated by the interest in investigating whether there is a correlation between the type of task proposed and the configuration adopted, and how it can allow a better impact. Although the available data do not form a statistic sample, it is interesting to highlight some insights.

We can observe that the preferred approach to deal with information and knowledge management problems, in which there is a need to locate and assemble information (as in the case of *COVID Near You, FluTracking, CovidTesting* initiatives) or to create collective resources (*Crowdfight COVID-19*) is the open crowdsourcing. This configuration, which allows the involvement of as many people as possible, seems to be the optimal one to perform the task Knowledge Discovery and Management. On the contrary, as regards the analysis of existing information on a large scale where human intelligence is more efficient or effective than computer analysis, harnessing the power a preselected community, with certain knowledge and skills, is ideal (as in the case of the Kaggle's data science and machine learning community). Instead, in the case of an ideation problem, in which solutions and technological projects are required, the Broadcast Search and the Peer-Vetted Creative Production are the best approaches. In this context, we found that the Broadcast Search has been implemented in all forms, leveraging the expertise and heterogeneous knowledge of NASA's employees (*NASA@work*), relying on a specific community

Table 1. Classification of the initiatives analyzed

	Internal crowdsourcing	Community crowdsourcing	Open crowdsourcing	Crowdsourcing via a broker
Knowledge discovery and management			• COVID Near You • FluTracking • CovidTesting • Crowdfight COVID-19	
Distributed human intelligence tasking		• Kaggle's CORD-19		
Broadcast search	• NASA@work	• Anti-Coronavirus Hackathon (TopCoder)	• Beat the Vid • CODEVID-19 global hackathon • EUvsVirus Hackathon • Solve's Health Security & Pandemics	• NineSigma • InnoCentive • Call4Ideas COVID-19 Challenge
Peer-vetted creative production		• CoVent-19 Challenge	• Idea Sospesa	

(*TopCoder's Coronavirus Hackathon*), through calls to participate open to everybody, without any pre-selection (*Beat the Vid, CODEVID-19, EUvsVirus Hackathon, Solve's Health Security & Pandemics*), and setting up specific calls via innovation brokers that connect potential creator and problem solvers with organizations seeking new ideas or specific solutions (*NineSigma, Innocentive, Openinnovability's Call4Ideas COVID-19 Challenge*). Finally, concerning the Peer-Vetted Creative Production, we noted that one initiative (*CoVent-19 Challenge*) was directed to a specific and qualified community composed by engineers, innovators, designers, and makers, while the other, *Idea Sospesa*, was open to any kind of contributors intending to gain access to the brightest ideas out there.

By varying the configuration and the task, the motivation and rewards change, as well as the way intellectual property is managed. For example, in the case of *Idea Sospesa*, the idea provider contributes without remuneration and without claiming any rights on the ideas; anyone is free to bring ideas on the platform, and it is expected participation for altruistic reasons, whereas both in the *CODEVID-19* and the *EUvsVirus Hackathon* the intellectual property of each project is owned by their respective proponents. As for the crowdsourcing via a broker, a recent study (Mazzola et al., 2018) has demonstrated that the different choices between different IPR arrangement depend on the attributes of the technical problem broadcast and that firms prefer to adopt specific acquisition mechanisms like value capture mechanisms to benefit from the innovation developed by the crowd.

Moreover, we tried to understand how private or public initiative funds help the success of these initiatives. In the following Table 2, we identified for each initiative the country, whether it is a public or private, the stakeholders involved, and the website. Limited to the initiatives analyzed, we can observe that since this is a global crisis, there are no geographical differences. Also, it is interesting to notice how private entities, such as accelerators (e.g. Marzotto Venture) or small teams of researchers (e.g. CoVent-19 Challenge), often with the support of public and private sponsors, have acted promptly to implement valuable projects and initiatives.

The diagram (Figure 1) shows the relationships between the stakeholders involved

The mix of resources and contributions from the crowd together with the economic and financial support provided by public sponsors is organized, integrated, and coordinated by the activities of the intermediary platform: as a result, new knowledge, innovative solutions, and collaboration between different and complementary actors are obtained.

6. Implications for research and development

Our results provide useful indications to support technological development, the R&D process, and the innovation management in general, and in the context of the COVID-19 pandemic in particular.

Evidence from the 16 projects suggests that across disparate domains, crowdsourcing produces novel and effective solutions. Results demonstrate that crowdsourcing can be an effective strategy for eliciting novel and effective solutions to health and economic challenges in the light of the COVID-19 pandemic. Confirming some advantages already known in the literature (Ghezzi et al. 2018; Wilson et al. 2018), the analysis of these initiatives has shown the benefits from crowdsourcing, such as quick scalability, decrease in process innovation lead time, high levels of collaboration (e.g. *Crowdfight COVID-19*), mitigation of trade-offs among cost, service/product-tailoring, and speed-to-market (e.g. *CoVent-19 Challenge*), possibility to bring people's knowledge out of their niche to find more creative solutions (e.g. *InnoCentive, TopCoder's Hackathon*), ability to channel efforts toward a common goal (e.g. *IdeaSospesa*), coordination of data collection and real-time information (e.g. *COVID Near You*). As we could measure in the initiatives already concluded, there has been large participation. The organizers of *Idea Sospesa* announced the success of their operation which led to hundreds of submissions, now available to all the stakeholders and ready to put into practice. Similarly, as reported by Ogrysko (2020), already by the end of April *NASA@work*, with more than 200 ideas submitted, has recorded a response that outpaced past challenges. The *Crowdfight COVID-19* initiative is putting together a constantly updated shared document, thanks to the help of its many volunteers, with a list of resources (calls, databases, news, funding calls, health care, computing and experimental resources) that may be of interest to any researcher. Crowdsourcing is low cost, rapid and it has the potential to accelerate research due to the amount of work that can be concentrated on a single challenge or a short event. Moreover, relying on specific communities that guarantee a certain quality level of know-how and experience is very useful in the case of more technical tasks. It is the case of the *CoVent-19 Challenge*, created to give an

Table 2. Crowdsourcing initiatives for COVID-19 emergency – Website URLs are active and working as of August 26, 2020

| Project	Goal	Type	Stakeholders	Country	Website URL
Call4Ideas COVID-19 Challenge	Seek projects useful to concretely support the Italian system in responding to the current emergency	Private	Citizens, companies, university, platform	Italy	https://openinnovability.enel.com/projects/CALL4IDEAS-COVID-19-Challenge
NASA@work	Gather employee ideas for ways their organization can help during the coronavirus pandemic	Public	Employees, government, citizens	USA	https://www.nasa.gov/offices/COECI/platforms/nasaatwork.html
Kaggle's CORD-19	Provide the global research community with the most extensive and updated data set on which to apply recent AI techniques	Public	Companies, government, individual researchers, university	USA	https://www.kaggle.com/allen-institute-for-ai/CORD-19-research-challenge
NineSigma	Identify innovative technological solutions	Private	Companies, individual researchers, platform	Worldwide	https://www.ninesigma.com/ressources/news/coronavirus-outbreak-working-together-for-the-future/
InnoCentive	Ideation and theoretical challenges to help mitigate the SARS-CoV-2 outbreak	Private	Companies, individual researchers, platform, public agencies	USA	https://www.innocentive.com/covid-19/
Anti-Coronavirus Hackathon (TopCoder)	Ideation challenge for social good	Private	Citizens, developers' community, platform	USA	https://www.topcoder.com/challenges/30119450
Solve's Health Security & Pandemics	Seeking tech innovations that can slow and track the spread of an emerging outbreak	Private	Citizens, companies, health-care ecosystem, tech innovators	USA	https://solve.mit.edu/challenges/health-security-pandemics
CoVent-19 Challenge	Create lasting solutions to the ventilator supply crisis	Private	Citizens, health-care ecosystem, tech innovators	USA	https://www.coventchallenge.com/
EUvsVirus	Collectively develop innovative solutions for technical, political, and social issues in the context of the coronavirus crisis	Public	Citizens, companies, public authorities, university	Europe	https://euvsvirus.org/
CODEVID-19 global hackathon	Realize useful apps to manage and survive during the COVID-19 pandemic	Private	Developers' community, citizens	Worldwide	https://codevid19.com/
Crowdfight COVID-19	Put the wider scientific community at the service of COVID-19 research	Private	Citizens, scientific community	Worldwide	https://crowdfightcovid19.org/
Beat the Vid	Collect technological project that can generate value for health-care professionals and patients	Private	Companies, health-care ecosystem, platform	Worldwide	https://opinno.io/beatthevid/
Idea Sospesa	Gather ideas to help the recovery of the small business	Private	Citizens, companies, government	Italy	https://www.ideasospesa.it/
COVID Near You	Identify current and potential hotspots for COVID-19	Public	Citizens, government, health-care ecosystem, university	USA	https://hms.harvard.edu/news/crowdsourcing-covid-19
CovidTesting	Create a list of COVID-19 testing facilities across the USA	Private	Citizens, government, health-care ecosystem, university	USA	https://www.openhealth.cc/
FluTracking	Detect and monitor the spread of COVID-19	Public	Citizens, government	Australia/New Zealand	https://info.flutracking.net/
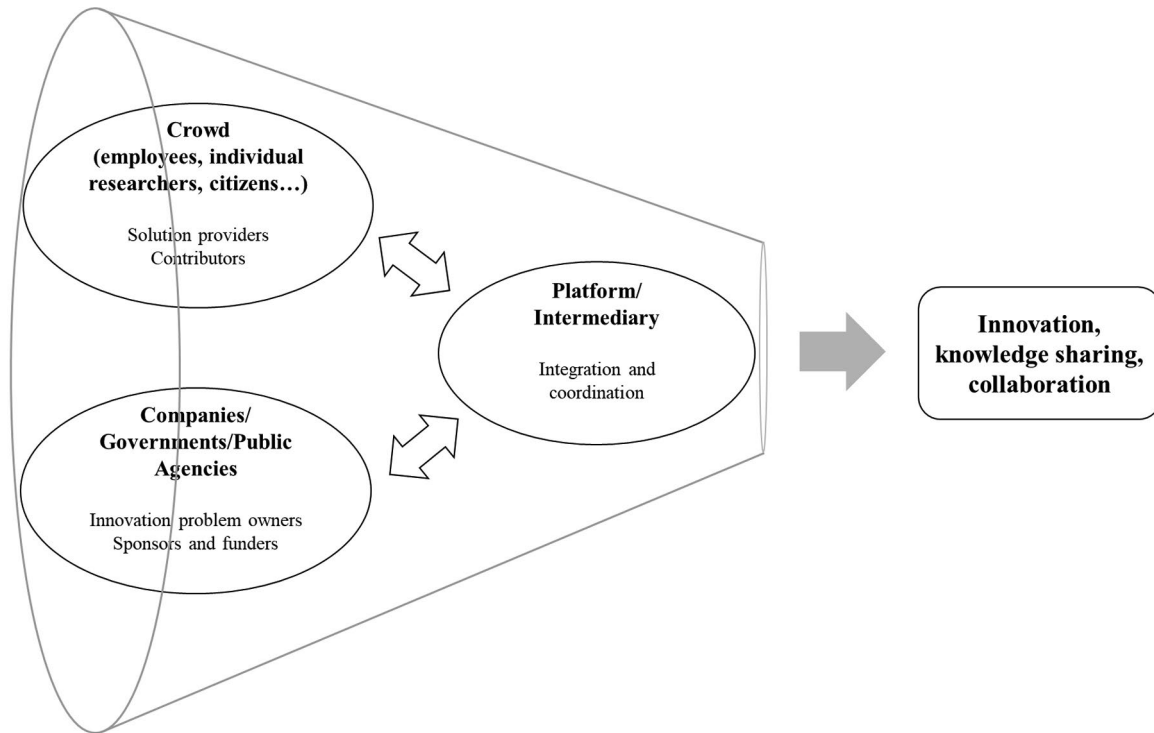
Figure 1. The interaction between stakeholders in the crowdsourcing process.

immediate response to the issue of the inability to provide invasive mechanical ventilation to all those in need, and which currently has seven proposals in the pipeline provided by its community of CAD experts.

At the same time, to avoid excluding possible contributors without these skills but who are interested and could meaningfully contribute, it is necessary to carefully solicit contributions. Hackathon events and open platforms are mechanisms to broaden access to contests and diversify the crowd. Also, as shown by Kohler (2015), since the success of crowdsourcing platforms hinges on the ability to attract the crowd to maximize the quality of creators, competitions like contests and hackathons help attract initial contributors. At a time like this when there is a need to act quickly and arouse interest in the widest possible audience, initiatives such as *EUvsVirus Hackathon, CODEVID-19 Hackathon,* and *TopCoder Anti-Coronavirus Hackathon* have proved to be very appropriate and functional for the purpose, because they have made it possible to obtain in a few days many relevant and valuable contributions. In the *TopCoder's Hackathon*, there were 126 registrants, 29 submissions, and 1 winning solution. Over 30,000 people from across the EU and beyond submitted 2,164 projects related to various domains including health and life (899), business continuity (381), remote working and education (272), social and political cohesion (453), digital finance (76), and other challenges (83); among them, the *EUvsVirus Hackathon* Jury chose and awarded 117 solutions. The winners will participate in an upcoming matching event with companies, investors, accelerators, venture capitalists from around the world to put their innovative solutions into production.

Another interesting lesson is the meaningful collaboration between institutions and research groups. The *CORD-19* data set available on Kaggle was born by the joint effort of the White House and a coalition of leading research groups and it represents the largest machine-readable coronavirus literature collection available for data mining to date. Finally, it is worth noting that even in this context it is possible identifying crowdsourcing techniques built on both passive and active data, as in the case of the app for tracking.

7. Conclusions

To the best of our knowledge, this paper is the first attempt to provide an overview, albeit inevitably limited and preliminary due to the continuous evolution of the situation, of the crowdsourcing initiatives deployed to help tackle the COVID-19 pandemic. After reviewing the existing literature on

the topic, we analyzed 16 crowdsourcing initiatives. On this empirical base, we observed a relationship between the kind of tasks (Knowledge Discovery and Management, Distributed Human Intelligence Tasking, Broadcast Search, Peer-Vetted Creative Production) and the crowdsourcing configuration type (internal; community; open; via a broker), noting a greater frequency of some combinations that suggest the greater appropriateness of the implementation of certain mechanisms for certain tasks. For example, as Pan et al. (2017) noted, innovation design contests for health are effective and low cost, and but many lacked outcome or process evaluation; the use of crowdsourcing intermediary crowdsourcing allows to overcome this issue since brokers can provide value-added 'orchestration' services to enable knowledge mobility and appropriability (Feller et al., 2012). Furthermore, we suggested important implications for innovation best practices for the future, arguing that crowdsourcing, through the involvement of crowds of both experts and ordinary people, can offer fruitful applications (from the design of new ventilators to ideas for the recovery of small business) that can provide actionable solutions to address the current health and economic crisis.

The value of these implications is not limited only to the current crisis. From these experiences, it is possible to learn how to be prepared and ready to face possible future outbreaks. The severe and sudden scenario generated by the COVID-19 pandemic has revealed the limitations of the usual organizational processes and the need for greater efforts in managing people and resources to respond adequately to an unexpected and devastating pandemic like this but like other similar events that might occur. Thanks to its potential as an innovative mechanism to leverage and coordinate a worldwide crowd of contributors through digital technologies, crowdsourcing can be one of the most promising solutions to respond to both medical-scientific and socioeconomic issues (Mazzola et al., 2020). It can also be used not only to identify solutions to a specific challenge, but also, by reversing the perspective, to enhance the systematic replication of existing local solutions accelerating their adoption at a global level.

This work is not without limitations. First, the approach adopted for gathering and selecting the initiatives was not systematic and relevant projects might have not been considered. Second, more research studies are needed to expand our understanding of the impact of these crowdsourcing initiatives, including studies with more data available on the participation, success and implementation rate of the solutions submitted, and qualitative studies on a broader sample of initiatives.

As Ebner et al. (2009) noted, there is a conceptual gap between the generation and the selection of ideas and their transformation into innovations. Future works should explore how this issue is handled in the context of crowdsourcing initiatives organized for the novel coronavirus emergency.

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