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The concept of an e-platform cooperation model in the field of 3D printing during the COVID-19 pandemic

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Abstract

The COVID-19 pandemic has caused unprecedented public health and economic crises around the world. The protection of human health and life has become the most important challenge. Disrupted supply chains resulted in shortages in the supply of essential medical equipment and personal protective equipment. The quick response to this situation was the use of 3D printers for the production of this type of article, especially for the medical service. The initial experience presented in this article (the review of solutions and initiatives based on cooperation in the field of 3D printing during the first wave of the pandemic) showed the challenges faced by organizations engaged in 3D printing during the pandemic. The performed identification and compilation of the difficulties that occurred during cooperation in crisis conditions allowed the author of this article to present an original proposal to minimize the most important of these problems. The main purpose of the article is to present the concept of a cooperation model based on an internet platform in the field of 3D printing during the COVID-19 pandemic, which will allow to increase the efficiency of management of activities necessary in crisis conditions.

Keywords: e-platforms, management, crowdsourcing, Covid-19 pandemic, additive manufacturing

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1. Introduction

The outbreak of coronavirus disease in 2019 (COVID-19) caused by the SARS-CoV-2 virus in China inhibited the supply of key components to manufacturers in Western Europe. The pandemic has disrupted existing globalization-based supply chains and freezes countries' economies in many industries. Large corporations as well as smaller producers sourcing inputs from remote locations faced shortages of raw materials and goods due to pandemic lockdowns. Supply chain disruptions made production difficult or even impossible.

The most important challenge during the outbreak of the first wave of the pandemic was the lack of personal protective equipment saving human health and life. As a response to the emerging crisis situation, science and innovation communities have made a fundamental contribution to tackle the crisis. During the first months of the pandemic outbreak, 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 supporting the health sector.

Enabled by global digital connectedness, collaboration has become a constant theme throughout the pandemic, resulting in the expedition of the scientific process, rapid consolidation of global outbreak data and statistics, and experimentation with novel partnerships. The quick response to this situation was also the use of 3D printers [1-3], which resulted in an increase in decentralized additive production [4-5].

The community's efforts to supply hospitals focused on addressing different shortages and bringing together many micro-production sites to have an aggregate support for the growing real-time need [2]. This was possible owing to community involvement and online cooperation platforms for 3D printing [6]. Adopting an open and collaborative approach and joining forces has become essential in the fight against the COVID-19 crisis. Also, the involvement of crowds as innovation partners was a great support.

The initial experience additionally showed the challenges faced by organizations engaged in 3D printing during the pandemic. The performed identification and list of problems that appeared during cooperation in crisis conditions allowed the author of the article to present an original proposal to minimize the most important of these problems. The main purpose of the article is to present the concept of a cooperation model based on an internet platform in the field of 3D printing during the COVID-19 pandemic, which will allow to increase the efficiency of management of activities necessary in crisis conditions.

2. Background

2.1. Information and Communication Technology (ICT) tools during the COVID-19 pandemic

Extreme disruptions are events that interrupt the regular flow of goods or services within a system [7] such as pandemics. Extreme disruptions have devastating effects for business and supply chain performance [8], and hence companies and enterprises efficiency, profitability, and survival. Their effects are multiplied and exacerbated as manufacturing, services, and commerce are globally connected [9-10]. Driven by the fact that the safety of companies and enterprises is crucial for the global economy [11]. it is important that they have in place plans for securing business continuity, defined as "identifying and managing the risks which threaten to disrupt essential processes and associated services, mitigating the effects of these risks, and ensuring that recovery of a process or service is achievable without significant disruption to the enterprise" [12]. To this end, companies and enterprises use technology and hence digital technologies [13].

The COVID-19 threat, school closures and social distancing recommendations have necessitated a shift in ways and styles of working, a modification of action plans and strategies, a change in people management and implementation of new solutions [14-15]. The COVID-19 pandemic has caused many business processes and human interactions to migrate from real to telecommunications space [16-17]. All industries have seen an increased interest in digital tools that facilitate remote work and help maintain business continuity without the need for physical meetings or presence in office, unless they are necessary [18-19]. Information and Communication Technology (ICT) solutions have enabled remote work and communication [20-21]. A large number of innovative solutions have also emerged that rely on remote collaboration within online information exchange, cooperation and knowledge-sharing platforms [2].

The home office concept relies mostly on teamwork. Employees need to communicate, hold teleconferences and customer meetings, collaborate on project implementation or use shared calendars. All those activities require an appropriate platform. Many of the solutions on the market are successfully used for remote work in the pandemic period. These include but are not limited to:

- Microsoft Teams [22],
- Team Viewer [23],
- Slack [24],
- Skype [25],
- Zoom [26].

Project management is a particular type of group work. It involves scheduling, team building, assigning tasks and holding people accountable. In this area, there is also a range of solutions that support employees working on home office projects, such as:

- Asana [27],
- Basecamp [28],
- Manage it [29],
- Trello [30].

Despite the advanced ICT tools, the pandemic has caused extreme disruptions [13] that have interrupted the regular flow of goods or services in the system [7]. These situations have had a crushing impact on business activity and supply chain efficiency, and therefore on the performance, profitability and survival of many businesses. Their effects are multiplied and intensified when production, services and trade are globally interconnected [9, 10].

However, COVID-19 has contributed to the emergence of new dimensions of cooperation. In 2015, the Boston Consulting Group (BCG) [31] established the percentage of companies identifying themselves as 'strong innovators' that had adopted ideas created as a result of collaborations with other companies at 65 percent. In 2018, BCG [32] found out that this figure had grown considerably. 83 percent of 'strong innovators' built partnerships outside their own companies, often cooperating across multiple industries. More and more businesses that used 3D printing admitted that they had established business relationships across sectors, boundaries or even competitors, with the aim to share ideas, build joint projects and drive customer value. Digital manufacturing is based on an ecosystem mentality, and cooperation has become critical to success. Owing to this approach, already in the initial weeks of the coronavirus outbreak, despite the global supply chain disruptions, it was possible to respond to the huge deficits in and even more immense demand for personal protective equipment (PPE) for healthcare facilities.

2.2. Initiatives for 3D printing during the COVID-19 pandemic

In response to the European Commission's call [33] for support in the fight against the COVID-19 pandemic, a range of initiatives and online platforms have been set up to bring together the 3D printing community in a technology-driven, cross-border, fast and effective pandemic control strategy. This has fuelled the evolution of the global network of 3D printing community volunteers and experts, which pushes towards the optimum use of the regional 3D printing capabilities for a supra-regional response to primary product shortages and supply chain disruptions [4]. The community's efforts to supply hospitals were focused on addressing different shortages and bringing together enough micro-production sites to have an aggregate support for the real-time need [2].

For instance, in Europe, in the initial days of the outbreak in Italy, Isinnova and FabLab engaged themselves in printing ventilator spare parts (valves) for a hospital in Brescia. When they succeeded, more 3D printing companies followed suit and started supporting Italian hospitals in the same manner [5]. Lombardy-based WASP [34] has taken up printing of custom face masks for individual wearers which reduce skin irritation related to long-term use. In Spain, the second most pandemic-affected country after Italy, a group of 800 people representing the 3D printing industry (engineers, designers and individual enthusiasts) set up a co-working group. 3DCovid19.tech [35] is a not-for-profit platform which accepts orders from hospitals and publishes new ideas, files and printing instructions for protective supplies and accessories. The platform enabled taking orders from 11 hospital centres in Barcelona, Madrid, Castilla-La Mancha and Andalusia in less than 24 hours.

3D printing has played a key role in countering the pandemic in Poland as well. For instance, there was the grassroots initiative #DrukarzedlaSzpitali [36], in which 3D printers, designers, engineers and volunteers worked together to develop replacement goggles, visors or ventilator T-tubes. Many universities and schools throughout Poland have become engaged in manufacturing of this kind of medical equipment [37]. Engineers and designers from Urbicum in Krakow [38] have joined their forces in the VentilAid project. They are designing an open source ventilator [39] that can be reproduced using a 3D printer and a set of basic and easily available parts. The Łukasiewicz Research Network and the Institute of Biocybernetics and Biomedical Engineering are developing a device that will enable sharing one ventilator between two patients.

Many platforms have been created globally to coordinate support in the fight against the pandemic. One of the largest 3D print/AM application databases in response to COVID-19 was launched on the 3D printing website of the US National Institutes of Health, which cooperate in this respect with the AmericaMakes initiative and the Department of Veterans Affairs. Royal DSM, a global science-based company operating in the nutrition, health and sustainable living sectors, launched UNITE4COVID, a digital, open, collaborative marketplace designed to provide solutions for healthcare professionals, as well as a forum and collaboration hub for inventors, manufacturers and certification labs in the fight against the coronavirus. The European Cluster Collaboration Platform (ECCP) set up the COVID-19 response forum, and the Enterprise Europe Network launched the European cooperation platform for care & industry together against CORONA.

It is impossible to mention all the initiatives here. Many businesses and individuals engaged in 3D printing globally, including such giants as Stratasys, Hewlett-Packard (manufacturer of 3D printers), Materialise (Belgian provider of 3D printing services), or PrusaPrinters (Josef Průša's company in the Czech Republic), have published free 3D printing models of accessories for the fight against the pandemic on their websites. Thingivers and myminifactory are the most famous sites, and so is CAR3D, the first European 3D printing project to create COVID-19 protection equipment. Siemens, too, has opened its Additive Manufacturing Network (AMN) platform to support efficient design and 3D printing of medical components needed by hospital staff to counter the COVID-19 pandemic.

2.3. The role of crowdsourcing during the COVID-19 pandemic

Jeff Howe introduced the term crowdsourcing in 2006 [40]. which refers to "the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call".

Crowdsourcing classically means involving a large number of people who work collectively to solve a problem or to complete a task with some objectives adhering to an adage—No one knows everything, but everyone knows something—collective intelligence [41]. Crowdsourcing refers to the activity of broadcasting a task to a large and undefined crowd rather than to a designated organisation, team, or individual [42].

Crowdsourcing is increasingly performed via the Web, which enables the interaction with a plurality of contributors all over the world [43]. Dedicated information systems that integrate human and computational agents facilitate the process of sourcing and aggregating contributions from the crowd. These systems are called crowdsourcing systems and form a significant boundary-spanning object between an organisation and its environment [44].

Besides various non-profit crowdsourcing applications like the Wikipedia and OpenStreetMap projects, commercial usage of crowdsourcing becomes more and more interesting and a large variety of crowdsourcing platforms has developed. These platforms act as mediator between the employers and the crowd. Some crowdsourcing platforms are specialized on certain tasks, e.g. InnoCentive on research and development, Clickworker on text creation, data categorization, web-search and surveys. Other platforms like MTurk, Microworkers or ShortTask offer a framework to access the crowd which enables the employers to submit individually designed tasks. These non-specialized platforms are particularly interesting as they have usually large crowds and are used for a large variety of different task types, like tasks related to search engine optimization, audio transcription of sound data, user surveys for products or recruiting people for scientific on-line tests [45].

Engaging in crowdsourcing activities allows companies to establish working relationships with external providers that possess specific know-how, improve new product development processes, and reconfigure their supply chain more efficiently [46]. Crowdsourcing also enables the organiser/seeker to access marginal solvers that possess fairly unrelated knowledge [47]. Crowdsourcing is, thus, not only a very fast response but it also provides access to solutions coming from distant knowledge domains. Oftentimes, adequate solutions exist elsewhere and we just don't know about them.

The current pandemic has brought together researchers and clinicians from all over the world to crowdsource their innovative ideas, disease - related data, and resources to quickly develop the treatment guidelines and research strategies [48]. For example, implementing crowdsourcing in the medical and pharmaceutical R&D context has allowed scientists and researchers to coordinate the collection and analyses of large-scale data to develop rapid research responses to crises such as disease outbreaks [49-50]. Crowdsourcing was used to collect and analyze data, aid in contact tracing, and produce personal protective equipment by sharing open designs for 3D printing. An international consortium of entrepreneurs and researchers created a ventilator based on an open-source design [51]. The zeal with which the scientists are collaborating worldwide with unwavering unity to confront the virus is unprecedented and unparallel. It has provided a new impetus to the progress of science. This crowdsourcing and global collaboration are especially crucial for developing countries lacking health resources and comprehensive research infrastructure [41].

In conclusion, the COVID - 19 pandemic has certainly opened up new avenues for crowdsourcing and global collaboration through virtual meetings and networking for research in medicine and healthcare, as well as to harness the human intelligence and creativity of a large number of people residing in developing countries with scarce resources [41].

3. Identification and compilation of difficulties during cooperation in crisis conditions

Businesses, universities, schools, research institutes and individuals around the globe have united, using their 3D printers to supply PPE to local hospitals, emergency departments, medical staff and people in need. The community's efforts to supply hospitals focused on addressing different shortages and bringing together a large number of micro-production sites to have an aggregate support for the growing real-time need [2].

The already discussed collaborative 3D printing initiatives in support of the fight against the SARS-CoV-2 coronavirus played a considerable role in supplying PPE to those in need, mainly hospitals. Most of them were rapidly launched grassroots initiatives to supply hospitals and the healthcare system with the means and equipment they needed to save human lives. This was possible owing to community involvement and online cooperation platforms for 3D printing [6].

The initial experience additionally showed the challenges faced by organizations engaged in 3D printing during the pandemic. Firstly, the interrupted supply chains, lockdowns and closed borders led to shortages in supplies of products, materials and production inputs, including 3D printing filaments. In response, commonly available materials were used, such as PET bottles in the case study discussed in this paper.

It was also a challenge during the pandemic to filter big data sets with a view to identifying real-time genuine needs, mainly in an effort to match the needs of medical services to community partners and volunteers who had the capabilities to manufacture PPE and the necessary equipment for hospitals and healthcare services. This was done by means by spontaneous collaborative platforms which supported matching the demand side with 'printers' and volunteers offering their assistance.

Another challenge was to find and catalogue proven designs and to adapt them to the manufacturing capabilities of individual printers.

Most PPE designs were published by private individuals on various online 3D printing community websites and had not undergone any official functional testing, approval or certification processes that are usually required for PPE, and even more so for medical devices [4].

What is more, volunteers who manufactured equipment for healthcare professionals faced logistics issues. They were dispersed, and therefore it was a huge challenge to supply the required materials to printers, to collect their products and to deliver them to hospitals. There was a need for reliability and mitigation of incremental risk. In Poland, the military, voluntary fire-fighting services and even Poczta Polska (Poland's state-owned postal operator) often came to the rescue in the case of logistics problems. Moreover, a number of companies sponsored bicycle rentals for volunteers or purchased bicycles for their staff to help them deliver the equipment to the point of use without taking any additional risks.

The SARS-CoV-2 pandemic has also contributed to negative environmental impacts due to the use of large quantities of disposable masks, protective clothing, plastic visors and PPE components [52]. Epidemic control supplies litter our streets, woods, rivers, seas and oceans and are washed ashore all over the globe. Many people discard their masks and protective gloves in recycling containers, creating a hazard to waste separation and collection workers. Therefore, the possibility of safe recycling (with prior decontamination) and reuse of these materials should be contemplated [53], as well as the development of proper infectious waste management [54].

4. The concept of the platform cooperation model for 3D printing in COVID-19 conditions

In response to the above-mentioned problems, the authors of the paper put forward a concept of an e-platform cooperation model in the field of 3D printing during the COVID-19 pandemic presented in Fig. 1.

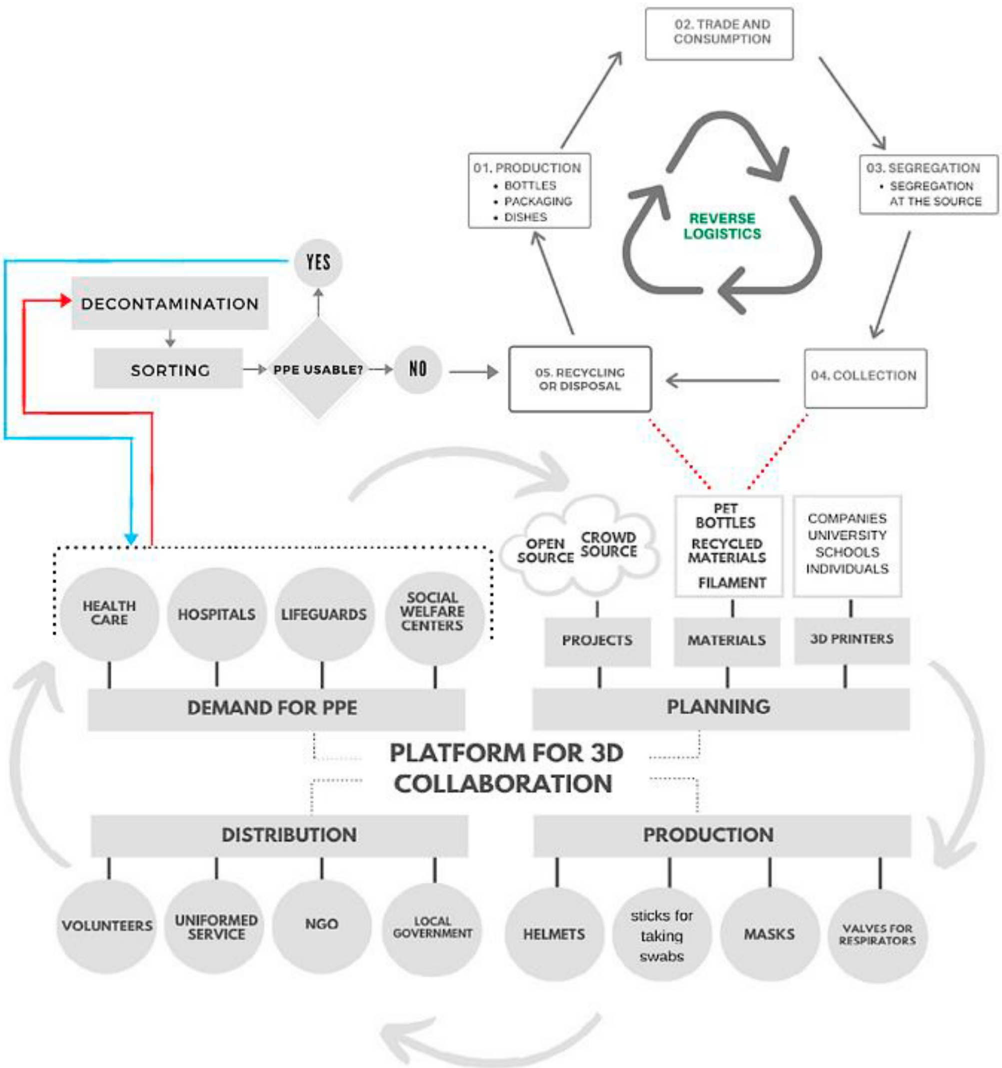

Fig. 1. The concept of an e-platform cooperation model in the field of 3D printing during the COVID-19 pandemic. Source: own study.

The concept presented herein brings all interested parties together in a collaborative platform. Its purpose is to match the demand side (healthcare services, hospitals, paramedics, social workers) to community partners who have the capabilities to manufacture PPE and the necessary equipment – enabling them to use tested and proven solutions (open source and crowd source 3D printing designs/models) and to volunteers who will distribute the required materials (such as PET bottles) and deliver 3D printing products to the point of destination. In this respect, a significant role is also played by public interest organisations and regional and local authorities [55] This is particularly important due to the sense of security and trust in the area of online collaboration platforms [56-57].

In view of the availability of PET as an input for 3D printing, the concept for the platform model includes the concept of reverse logistics and cooperation with local waste collection, recycling, processing and disposal companies [58]. PET packaging waste management can take different forms. PET is usually obtained as a result of a selective collection process organised within a specific agglomeration, using specially designed containers. However, it is important to emphasise that during selective collection from citizens, PET is collected together with other plastic waste. This necessitates additional processes to separate this specific waste [53].In view of the 'littering' of the environment with pandemic waste, the need to include operators engaged in the reuse [59-61] and recycling of single-use PPE has been taken into account in the concept for the platform model. This process encompasses decontamination and disinfection, as it often involves PPE and infectious waste which necessitate appropriate decontamination and disinfection methods and procedures [62]. Especially that studies in this area are ongoing, they are being tested and often put into practice [63-64].

In additive manufacturing, volatile organic compounds are released that have a negative impact on human health. Adequate ventilation is required during simultaneous printing on multiple printers [65]. Due to the large amount of waste heat, its recovery should also be considered, which will significantly improve the energy efficiency of additive production. Heat recovery can be compared to heat recuperation in paint shops [66], in particular spray booths, where air is exchanged [67] or the use of heat pumps that enable high efficiency [68]. It is therefore reasonable to place in the platform a module with information on places with adequate ventilation and heat recovery, where there is a possibility of collective placement of printers. However, it is important to consider the need for sufficient distance and other safety measures to prevent transmission of infection.

5. Conclusion

During the first wave of the pandemic, a range of initiatives and areas of cooperation have been created to bring together the 3D printing community to manufacture and supply PPE to local hospitals, emergency departments, medical staff and people in need. This has fuelled the evolution of the global network of volunteers and experts from the 3D printing community that sought to optimize the use of regional 3D printing capabilities for a supra-regional response to primary product shortages and supply chain disruptions [4]. This initiative would not be possible without the involvement of a number of parties such as businesses, universities, research institutes and private individuals. This type of rapid, crowd sourced, design and production resulted in new challenges for regulation, liability, and distribution. A combination of factors must be met to create and maintain such alliances (Manero et al., 2020). Equipment and space for 3D printing are critical, of course, but civic involvement is just as important.

The initial experience discussed in this article showed the challenges faced by organizations engaged in 3D printing during the pandemic.In order to improve the crisis response during the COVID-19 pandemic, space for online cooperation must be provided in the form of internet platforms enabling sharing and reviewing of insights and information and coordinating action, all to integrate dispersed manufacturing into a concentrated effort. On the basis of the above experiences, it was concluded that the main part of the development of means of responding to crisis situations should be an internet platform containing an information bank and modules for communication and optimization of the issues described above. The main feature of such a platform should be its scalability and ease of extension with additional modules.

The article proposes an original concept of a cooperation model based on an internet platform in the field of 3D printing during the COVID-19 pandemic, which will allow for more effective management of activities necessary in crisis conditions. The future research should focus on improving the performance of such platforms, verifying and enhancing 3D printing designs, and improving the management of the necessary crisis response activities.

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