

R&D and Innovation Approaches in the Postpandemic Period

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Prof. Hasan Mandal attained his PhD degree from Newcastle University in 1992. Post-doctoral studies were undertaken at Newcastle University (1992-1994) and Karlsruhe University (1997-1998) as an Alexander Humboldt scholar. In 1994, Mandal became Assistant Professor in the Department of Ceramic Engineering at Anadolu University, receiving an Associate Professor status in 1996 and tenured Professor status in 2001. With more than 140 publications, 72 in SCI journals, an h-index of 19, 1490 citations and 6 international patents, Prof. Mandal holds various national and international awards, including the TÜBİTAK Science Award. He is a member of TÜBA, World Academy of Ceramics and Academia Europaea. Prof. Mandal was appointed as a member of Council of Higher Education (CoHE) in March 2015, elected to the Executive Board of CoHE in April 2015 and the Deputy Chairman of CoHE in July 2016. Prof. Mandal served in these positions until January 2018 and as Deputy Rector of Sabancı University from January to February 2018. He was assigned as the President of TÜBİTAK on February 22, 2018, appointed as a member of the Presidential Science, Technology and Innovation Policies Council on October 8, 2018 and elected as the acting president since November 1, 2018. He was elected as the board member of the Council of Higher Education in April 2019.

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Abstract

The transformation that is being realized in R&D and innovation processes, including co-creation and systemic challenge driven innovation, has become an imperative during the pandemic. In this chapter, the main features of the transformation in R&D and innovation processes are first put forth and its importance in the combat against the pandemic is evaluated. Afterwards, the novelties of the science and technology-based process in our country to combat COVID-19 are discussed under three main headings. In this context, the coordination of the ecosystem based on a co-creation approach with a focus on succeeding together foremost in vaccine, drug and diagnostic solutions under the COVID-19 Turkey Platform are set forth. Rapid calls that enable ecosystem actors to actively take part in the fight against COVID-19, thereby strengthening the mobilization, are reviewed based on new opportunities for SMEs, young researchers, the social sciences and humanities as well as support for entrepreneurs. In the race against time, developments for accelerating R&D and innovation processes as well as increasing the scientific communication environment are put forth based on an online portal and virtual conferences. In the new normal order, the guiding aspects of these experiences are discussed, especially where tackling common challenges will continue into the future in biosecurity, cyber security along with broadband infrastructure and food supply security. As one of the most essential components of the social system, the R&D and innovation system has undergone a multi-faceted experience due to the pandemic, which will elevate co-development solutions to a new dimension in the post-pandemic era.

Keywords

Research, development, innovation, co-creation, vaccine, drug, COVID-19, pandemic

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Introduction

Transformation in R&D and Innovation Processes

The new coronavirus disease (COVID-19), declared as a pandemic, has caused various difficulties in the social system. The need for approaches that can counter the challenges that need to be resolved, including the challenges caused by COVID-19, has moved to a dimension that has become more important than ever. In this environment, it was once again revealed that research, development (R&D) and innovation are critical in providing solutions. In a world where complex problems that need to be addressed at the social level are increasing, the necessity of the transformations in order to make R&D and innovation processes more effective has increased rapidly. Features that are determined as basic elements of the transformation in the R&D and innovation processes and an evaluation of their importance during the COVID-19 pandemic period is summarized in Table 1. These key features are based on the report published by the European University Association (Reichert, 2019). As can be seen from the evaluations in Table 1, the transformation in R&D and innovation processes became compulsory during the COVID-19 pandemic period.

Table 1. Assessment of the Key Features of Transformation in R&D and Innovation Process and Its Importance in the Scope of COVID-19 Outbreak

Previous Feature	Transformed Feature	Evaluation of its Importance During the COVID-19 Outbreak
Linear innovation	→ Reiterative innovation	✓ Providing speed to R&D and innovation-oriented solutions
Closed innovation	→ Open innovation	✓ Inclusion of necessary resources in R&D and innovation processes
Technology-driven innovation	→ Systemic challenge driven innovation	✓ Combatting the challenge in a multi-faceted manner

Previous Feature	Transformed Feature	Evaluation of its Importance During the COVID-19 Outbreak
Individual innovation	→ Cooperative and multi-disciplinary innovation	✓ Actors coming together for more effective solutions
Spontaneous innovation	→ Systematic innovation	✓ Emphasis on the importance and urgency of strategic approaches
Innovation focused on knowledge transfer	→ Co-creation based innovation	✓ Emphasis on common processes leading to the path to success
Innovation projects	→ Innovation culture	✓ Ensuring that a sustained paradigm shift takes place

Iterative innovation is among the transformed features in Table 1. This feature implies increasing the interactions between the stages and evaluating the scientific accumulation for different solutions instead of monitoring the R&D and innovation stages linearly. Iterative innovation is an important feature that can accelerate R&D and innovation processes when compared to the requirements of COVID-19 processes. Open innovation, on the other hand, reveals the importance of including necessary resources in R&D and innovation processes, independent of institutions and organizations (Chesbrough, 2020). From this point of view, it requires that qualified knowledge and qualified human resources, which are the most important resources, are evaluated and included in the process throughout the ecosystem. It is also emphasized that open innovation is among the important features that contribute to the management of important crises, such as the COVID-19 outbreak (Chesbrough, 2020).

Prior to the COVID-19 outbreak, it has been widely recognized that sustainable development-oriented challenges not only involve a technological challenge but also represent a social challenge that extends to new business models and requires various socio-economic innovations (Colvin vd., 2014) which originated from the SLIM (Social Learning for the Integrated Management and Sustainable Use of Water at Catchment Scale). The importance of this feature, which is expressed in Table 1 as systemic challenge driven innovation, has increased during the COVID-19 pandemic. In order to comprehensively address the problems caused by the pandemic at the social level, it was necessary to develop solutions with a multi-faceted approach based on science and technology. Within this approach, the need and awareness for R&D and innovation processes based on cooperation and multi-disciplinary approaches among ecosystem actors in bringing solutions instead of individual innovations has increased. The common struggle approach that emerged during the COVID-19 pandemic period included experiences underlining that solutions based on ecosystem actors coming together can be significantly more effective.

In environments that require tackling challenges, spontaneous innovation has been replaced by processes in which strategic approaches are followed. This feature, expressed as systematic innovation in Table 1, requires ecosystem

actors to follow more planned and targeted processes. The COVID-19 outbreak that emerged as an unexpected pandemic has been a spontaneous development. However, when we look at our country, a science and technology based process in which emergency planning was made by determining a strategic approach for the ecosystem was followed immediately. Within this common struggle approach in our country, innovation focused on co-creation have been an important opportunity for the ecosystem. Processes in which knowledge is only transferred from one ecosystem actor to another has become insufficient. It has become essential for different institutions and organizations to be involved in common processes across the ecosystem where work is done together collaboratively rather than only cooperation. In this context, while it was important to capture innovation-oriented innovation opportunities before the COVID-19 outbreak, this has become an imperative during the COVID-19 outbreak. The pandemic has been an important milestone showing how co-creation processes are mandatory. It has been understood that the path to success goes through processes in which the ecosystem works together in co-creation.

The acquisition of experiences that are suitable for supporting the transformation in R&D and innovation processes contributes to the creation of a common innovation culture. The interactions between the actors are expected to meet in impact-oriented processes that are based on a common innovation culture much beyond a process that consists of R&D and innovation projects. The culture of innovation focused on co-creation is also necessary considering its impact potential (Q-Plan, 2019). For this reason, a common innovation culture that takes place in Table 1 is also important for the COVID-19 pandemic period, which requires a process towards impact for a healthy society. Certainly, the common R&D and innovation culture that is strengthened to fight against the common challenge of COVID-19 will also be a guide after the pandemic for other areas that require solutions in the ecosystem.

Mobilization of the Ecosystem in the Fight Against COVID-19

At the present time, it is inevitable to make a clear distinction between “before COVID-19” and “post COVID-19” considering that the COVID-19 outbreak represents a new social challenge. With this milestone, the distinction between ecosystems that can and cannot evaluate the transformation in R&D and innovation processes to combat COVID-19 is also increasing. Positive developments will be provided for ecosystems that can realize the transformation in R&D and innovation processes during the fight against COVID-19 so that these ecosystems will emerge stronger after the pandemic and enter the normalization process with a new order. In this new order, COVID-19 outbreak experiences will open new opportunities with an approach towards combating and achieving common challenges based on the transformation in the R&D and innovation processes that have become an imperative.

When a more detailed assessment is made with a focus on Turkey, our country has put forward a comprehensive approach in the combat against COVID-19 and provided a strong example based on the transformation that is taking place in R&D and innovation processes. The ecosystem mobilization that our country has achieved in the fight against COVID-19 has included an approach that has been endeavored to be followed from all over the world and tried to be followed while expressing great appreciation. The interactions of the R&D and innovation ecosystem were mobilized for a common struggle based on science and technology in the face of the COVID-19 outbreak, and the ecosystem was fully mobilized. The main innovations that took place in the comprehensive mobilization of the ecosystem in the face of a common challenge that needs to be resolved are presented in three main headings. The developments of each are explained in the continuation of this chapter.

Innovation 1. Coordinating the ecosystem with a focus on collaboration based on a co-creation approach in mobilizing the ecosystem in the face of a common challenge

Ecosystem researchers were mobilized within the scope of a common platform in order to ensure an impact against the COVID-19 outbreak for a healthy society. In the COVID-19 Turkey Platform in which co-creation and succeeding together has come to the forefront, interactions between researchers have been increased and the ecosystem has been coordinated based on different R&D and innovation targets. In the fight against COVID-19, a total of 267 researchers have been united for providing solutions based on the development of treatment-oriented drugs and immunity-oriented vaccines. In addition to drug and development projects, the diagnosis area is also included in the platform.

Innovation 2. Opening rapid calls to ensure that ecosystem actors are involved in the fight against COVID-19 and the mobilization of the ecosystem is strengthened

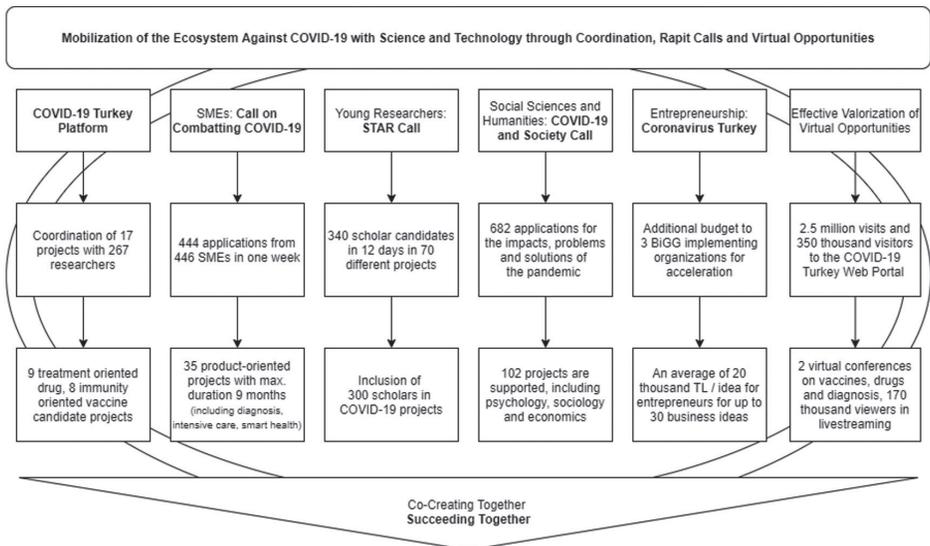
The COVID-19 pandemic has challenged social systems, especially the health system. A grand challenge with complexity and systemic difficulty was encountered at the societal level. It quickly become clear that this difficulty needs to be resolved and effectively handled with an approach that transcends disciplines. For this reason, new rapid calls have been opened and completed to effectively incorporate the contributions of the natural sciences, engineering, social sciences and humanities into the process and ensure that relevant ecosystem actors from all levels are involved in the process. These calls significantly strengthened the mobilization of the ecosystem from small and medium-sized enterprises (SMEs) and young researchers to social sciences and humanities researchers. Support opportunities are also increased to accelerate the business ideas of entrepreneurs.

Innovation 3. Valorization of virtual possibilities to accelerate R&D and innovation processes and increase scientific communication environments in the race against time

The enabling opportunities of digital technologies have been evaluated to increase the virtual environments in the pandemic period and to provide flexibility to the necessary processes. The use of virtual environments has been maximized to contribute to R&D and innovation processes, with the idea that every challenge can also create an opportunity. Effective valorization of virtual environments has been ensured from the organization of virtual conferences to conducting rapid processes, including the evaluation processes of the opened calls, sharing scientific resources and datasets within the scope of open science, and communicating ecosystem developments to large masses throughout the society.

In the framework of the main innovations as mentioned above, a summary representation of the science and technology-based combat against COVID-19 in our country is given in Figure 1. In this approach, the components of the ecosystem are brought together with a focus on a common challenge and a multi-faceted process is managed simultaneously on the basis of qualified knowledge and qualified human resources. In addition, in this approach, all the functional dynamics that accelerate innovation systems from providing direction and guidance to R&D and innovation processes to market formation are all integrated (Hekkert et al., 2007), (Bergek et al., 2008). To combat a common challenge, R&D and innovation were strategically directed, and output and impact-oriented knowledge production was increased, particularly drug and vaccine development against COVID-19. While the ecosystem is coordinated, the diffusion of knowledge has been increased with a focus on a co-creation and succeeding together approach. The contribution of the social sciences and humanities was integrated into the process, human resources were mobilized from young researchers to competent researchers, and entrepreneurs were encouraged to develop solutions against COVID-19. While product-oriented expectations from SMEs were increased, opportunities for increasing the widespread use and impact of the developed products were captured, such as the success in the mass production domestic and national respirators for addressing societal needs. With COVID-19 as a common challenge, an ecosystem with unity in direction between actors is achieved and country-specific co-creation models that represent a paradigm change in the transformation of R&D and innovation processes have been advanced and carried forward.

Figure 1. Mobilization of the Ecosystem in Combating COVID-19 on the Basis of Science and Technology



COVID-19 Turkey Platform in Ecosystem Coordination with a Focus on Succeeding Together

The first publication of the genetic sequence of the SARS-CoV-2 virus causing COVID-19 led to intensive R&D studies for developing vaccine candidates against the disease (Thanh Le et al., 2020). Simultaneously with the emergence of the COVID-19 outbreak before the disease had entered our country, possibilities to mobilize the competencies in the ecosystem were evaluated. In this context, stakeholders of the drug, vaccine and/or diagnostic-oriented research programs that have completed the first phase under the call of the TÜBİTAK 1004 Centers of Excellence Support Program on High Technology Platforms, which have an important place in the co-creation models specific to our country, were taken into consideration. Under the patronage of the Ministry of Industry and Technology and the coordination of the TUBITAK Marmara Research Center Genetic Engineering and Biotechnology Institute, solutions from the ecosystem for drug candidates for the treatment of the COVID-19 infection caused by the SARS-CoV-2 virus and vaccine candidates for immunization were collected and a sub-platform was created specifically for their realization.

In the mobilization that was launched as the COVID-19 Turkey Platform, the submission, evaluation and finalization of drug and vaccine development research projects that were written for the collected solution areas were completed in a total of 10 days. Initially, 14 research projects were put in implementation, including both chemical and biotechnological drug and vaccine projects based on different methods and including more than one solution possibility. Although a dynamic process, currently 267 scientists from 46 different institutions and organizations, including 29 different universities, 8 different private sector organizations and 9 public R&D units in 17 projects, achieve significant success by conducting intensive research studies collectively. 116 of the researchers contribute from universities, 67 from public R&D units, 38 from the private sector and 46 as scholars in the research projects.

Within the scope of treatment-oriented drug development projects, drug molecular modeling and design, synthesis and production of domestic synthetic drugs, convalescent plasma and recombinant neutralizing antibody projects are conducted successfully. Already in the first 2 months of the projects, virtual scanning of thousands of molecules according to the different target regions of SARS-CoV-2, designing a new drug molecule, synthesizing and formulating drugs with local possibilities, moving to animal immunization studies for recombinant neutralizing antibody and progress in protective artificial antibodies have been reached. In vitro demonstration of the neutralizing effect for protein-based treatment opportunities and other similar developments have been achieved with intense efforts in collaborative teams.

There is an important portfolio of vaccine candidates in the vaccine development projects for immunization, including all vaccine methods that are studied in the world as well as innovative methods. In this context, both inactive vaccine

candidates and vaccines based on high-technology are included in the vaccine candidate portfolio, including recombinant protein and peptide vaccines, DNA vaccine, adenoviral viral vaccine, virus-based particles-based vaccine, ASC granule-based vaccine and RNA vaccine candidate. Animal studies, which are an important step for basic science in pre-clinical research, have been started in half of the vaccine projects within the first 2 months. In other vaccine development projects, animal models are developed for COVID-19 in order to progress to animal experiments.

The most important feature of the platform, which includes pre-clinical research projects with a duration between 9 to 12 months, is that the researchers work together in synergy, not independently from each other. There is a robust sharing of information on any needs that are encountered even among research projects involving different methods as well as the sharing of materials and human resources, which has also become the common culture of the platform rather than unusual activities. This approach, as in the defense industry, expresses a process that is focused on success with continued determination for the development of domestic and national technology solutions for the people of our country in the field of vaccine and drug-oriented health. The full-scale mobilization and coordination of the ecosystem that is represented in the COVID-19 Turkey Platform drug and vaccine research projects is also extended to other relevant areas of research, including in particular the areas of diagnosis.

Rapid Calls Oriented Towards Involving Ecosystem Actors in the Process

The accumulation of R&D and innovation assets in the healthcare field has played a major role in mobilizing the ecosystem against COVID-19, which creates a new scientific gap for the world. The scope of support that is given by TÜBİTAK, which focuses on pre-clinical research projects, amounted to a budget of approximately 2.3 billion TL for 2,960 projects in the last 5 years. This amount includes 755 vaccine and drug R&D projects with a total budget of 1.7 billion TL, as well as 516 projects with a total budget of 402 million TL in the field of medical devices, including diagnostic kits. Considering this important accumulation of competence, which constitutes the basis for the mobilization of the ecosystem, ecosystem actors have been included in the process by means of rapid calls to fight against COVID-19. As part of the transformation in R&D and innovation processes, the “Call for Combating COVID-19” for SMEs, the “Intern Researcher Scholarship Program (STAR)” call for young researchers and the “COVID-19 and Society: The Social, Human and Economic Effects of the Pandemic, Problems and Solutions ” call have provided important opportunities for the ecosystem within the scope of the transformation in R&D and innovation processes.

Call for Combating COVID-19

Within the scope of the “Call for Combating COVID-19” for SMEs that are important actors for solutions in the ecosystem, a total of 444 project applications were received from 446 SMEs during the 1-week period during

which the call was kept open. In the call, SMEs were requested to develop product-oriented projects for the diagnosis and treatment of COVID-19, protective products that are effective in preventing disease transmission routes, and devices and products for improving environmental conditions. Through this rapid call that proved the power of SMEs once again, a total 35 projects received support decisions with a support budget of 13.5 million TL (TÜBİTAK, 2020a). The evaluation process of the rapid call was conducted completely online. In addition, the opinions of the hospitals and physicians as potential end users were integrated into the process to evaluate product-oriented expectations and were conducted in the scope of the evaluation process. The project applications were completed in less than 2 weeks with the evaluations of 552 referees and 18 Advisory and Group Executive Boards and became the quickest call that was completed by TÜBİTAK.

The ongoing projects involve fast and reliable diagnostic kits, innovative designs for devices that can be utilized prior to or during intensive care, cameras with various technical features, smart health solutions, telemedicine applications and support systems for early diagnosis and follow-up stages. Synthesis and production of disinfectants, innovative masks, materials and protective clothing represents other product-oriented project areas. The total support period of all projects focused on product and solutions with a maximum duration of 9 months. It is targeted that SMEs will achieve new areas of success based on product-oriented solutions against COVID-19 and make a significant impact based on the results of their products.

Intern Researcher Scholarship Program Call

It is a valuable opportunity to involve undergraduate, graduate and postgraduate students and post-doctoral researchers who want to take part in the fight against COVID-19 with the skills they possess in the process. To meet this opportunity, a first-time scholarship has been initiated through the STAR call for young researchers to work as a scholar in R&D projects that are related to COVID-19. The STAR call encouraged students and young researchers who will take part in publicly supported R&D projects for the diagnosis and treatment of COVID-19. An interface has been created to meet the demands of young human resources in the R&D projects related to COVID-19 in a way to contribute to the application process.

In the 12 days that the call was open, applications were received by 340 undergraduate, graduate and postgraduate students and post-doctoral researchers who wanted to work in 70 different research projects. In this context, scholarship candidates across all levels showed great interest to contribute to the process with their skills and wanted to work in R&D projects to combat COVID-19. In total, 118 undergraduate, 85 graduate and 70 doctorate students, together with 27 post-doctoral researcher candidates who satisfied the basic conditions to become scholars were supported to take part in research projects related to COVID-19. By supporting 88% of the scholarship candidates that applied, 300 young people in total were matched with needs in

R&D projects related to COVID-19. In addition, 209 of the 300 young scholars who were included in the process were female researchers (TÜBİTAK, 2020b).

The 300 scholars who are supported through the STAR scholarship are taking roles within R&D projects related to COVID-19 with public support, including the research projects in the COVID-19 Turkey Platform. In addition to vaccine and drug development as well as diagnostic kits projects, the young researchers are supported for a maximum of 12 months in projects that include biomedical equipment, masks, protective clothing, disinfectants, and information applications that can directly or indirectly affect pandemic outcomes.

Social Sciences and Humanities Focused COVID-19 and Society Call

It is a requirement that the multi-dimensional effects caused by COVID-19 should be handled in multi-faceted ways. As emphasized within the scope of the transformation in the R&D and innovation processes during the pandemic period of COVID-19, the need for innovation with systemic difficulties came to the forefront. In this context, it is essential that the social sciences and humanities contribute to the process alongside natural sciences and engineering in the development of solutions in combatting COVID-19. Evidence-based planning based on science and technology that is possible with the contribution of the social sciences and humanities is important not only for the pandemic period, but also the post-pandemic period. Clearly, changes in individual, institutional, social, economic and environmental dimensions have occurred due to the COVID-19 outbreak. There have been radial changes from business methods, working models and education methods to producer and consumer behaviors, supply-demand balances, international supply chains, energy demands and quality of life. For example, an evaluation of impacts in supply chains in the short term and those for visibility, new risks, cost modeling and a resilience focus gains importance in the medium term (PwC Türkiye, 2020). Considering the problems triggered by such changes and the potential problems it will trigger, the social sciences and humanities have important contributions to make in better controlling the pandemic and increasing the resilience of the society.

In order to make a significant contribution to meeting all of these needs, TÜBİTAK launched the call on “COVID-19 and Society: Social, Human and Economic Effects of the Pandemic, Problems and Solutions” (TÜBİTAK, 2020c). The call aims to develop evidence-based solutions by investigating the current and predicted problems as well as the effects of the pandemic from a social sciences and humanities perspective. Research on short, medium, and long-term projection studies, forecasting, analysis and planning studies are carried out under this call with evidence based scientific findings that constitutes the social sciences and humanities contribution to the science and technology-based combat against COVID-19. In this way, solutions that will be beneficial for decision makers and implementers regarding the management of the processes and resource planning will be created. The call also emphasized that

interdisciplinary studies will be particularly important, since interdisciplinary approaches have an essential role in understanding the multidimensional effects of the global outbreak.

The call that remained open for 15 days received 680 project applications from Turkey and 2 project applications from the Turkish Republic of Northern Cyprus for a total of 682 project proposals from 160 different institutions. The number of applications that were received allowed this call to be one of the thematic calls in the field of social sciences and humanities to receive the most project applications. Within the scope of 102 projects for which support decision were given, problem and solution areas are being determined in psychology, sociology, computer and instructional technologies, communication, marketing, social policies, public administration, economics, management and organization fields. The total budget of 102 R&D projects with a maximum duration of 6 months is approximately 10 million TL. Social sciences and humanities research has been accelerated for providing rapid results to support future planning considering the multi-dimensional effects of COVID-19.

Accelerating and Encouraging the Business Ideas of Entrepreneurs

Alongside calls that are focused on SMEs, young researchers and researchers in the social sciences and humanities to strengthen the mobilization in the ecosystem, entrepreneurs have also taken their place in the process of combatting COVID-19 with innovative business ideas. The Coronathon Turkey Competition that was organized to allow entrepreneurs to be part of the solution involved the support of many organizations and institutions. The founding team included stakeholders that have been working together within the scope of the TÜBİTAK Individual Young Entrepreneur Program (BiGG), various entrepreneurship centers and non-governmental organizations. In the event, entrepreneurs competed with innovative business ideas towards providing solutions to social and logistics solutions as well as solutions in the scope of unemployment, cash flow problems and sustaining education (Coronathon Türkiye, 2020). Various innovative ideas have emerged with direct or indirect implications for the COVID-19 outbreak, including innovative financial technologies for money-free environments from devices that enable automatic disinfection of monetary surfaces.

Taking into account the important contributions that young entrepreneurs can provide to increase and diversify possible solutions against COVID-19, an additional budget of 600 thousand TL has been allocated to the accelerator programs of 3 implementing organizations that have been working together within the scope of TÜBİTAK BiGG for business ideas focused on combating COVID-19. In total, up to 30 business ideas are provided with an average of 20 thousand TL as a means of supporting innovative ideas to be transformed into solutions that touch human life and reach the market. Success stories similar to those that included security critical and cyber threat analysis software, three-dimensional printing technology, analysis platform that enables a

cheaper analysis of human DNA and others before the COVID-19 pandemic are targeted while strengthening the role of entrepreneurs in the common struggle by contributing to the acceleration of innovative business ideas.

Effective Valorization of Virtual Opportunities in the Race Against Time

In the race against time, the enabling role of digital technologies has come to the forefront in the COVID-19 pandemic environment to accelerate R&D and innovation processes, to develop smart solutions, and provide the necessary flexibility to processes that need to be maintained. Open access, open data and open science trends as indicated within the scope of the TÜBİTAK Open Science Policy (TÜBİTAK, 2019) have been significantly increased worldwide in the fight against COVID-19. In the face of a common challenge, the enabling role of digital technologies was evaluated and new virtual environments were created. As the new virtual environments of our country, the COVID-19 Turkey Web Portal has been created and virtual conferences were organized in the coordination of the COVID-19 Turkey Platform, reaching a wide audience. Through the effective valorization of virtual environments, the science and technology-based approach in combatting COVID-19 has been supported by strengthening the means of an interactive communication with the ecosystem.

COVID-19 Turkey Web Portal

Sharing evidence-based scientific developments has become a necessity in the fight against COVID-19. Starting from existing scientific sources, which have not previously been open access but could contribute to COVID-19 researches, leading publishers have given open access and COVID-19-specific publication collections have been created. The aim of providing a common online collection of various national and international databases based on open access to scientific resources, together with open data sets for the benefit of the research ecosystem and boosting social awareness led to the establishment of the COVID-19 Turkey Web Portal that has been sustained with continuous updates (STB/TÜBİTAK, 2020a).

Within a period of approximately 2 months, the number of visits to the portal has exceeded 2.5 million visits with a total of more than 350 thousand visitors. In addition, through the portal, scientific communication has been strengthened to bring scientific and technological developments to society. In the portal, daily statistics on the results of the COVID-19 outbreak, current scientific developments, scientific resources, datasets, useful links, means of protection and clinical studies, as well as competencies of our country and researchers are shared. Sharing of scientific information that have been added by researchers in the ecosystem include molecular dynamics simulations, the importance of various disciplines such as structural biology, and a COVID-19 diagnostic system supported by artificial intelligence. An new interface that is created using open data sets based on temporal and spatial data of the genome sequence of the virus is also shared through the portal (STB/TÜBİTAK, 2020b).

In addition to the announcements and developments related to the rapid calls in the fight against COVID-19, the special issue of the Turkish Journal of Medical Sciences, COVID-19 (Academic Journals, 2020), TÜBA COVID-19 Global Outbreak Evaluation Report (Şeker vd., 2020) and similar scientific sources are shared. In the special issue of the Turkish Journal of Medical Sciences, the epidemiology of the virus, preventive measures, diagnostic and radiology approaches, patient care and treatment options, the effects of the global pandemic and various responsibilities are discussed. With the contribution of the members of the Coronavirus Scientific Committee, scientific difficulties and the ongoing scale of the pandemic are undertaken in a multi-faceted way. The mobilization of the ecosystem that is pursued with determination to obtain a positive effect on a healthy society based on scientific advancements was also represented (Mandal, 2020). Thus, through the special issue, the production of scientific knowledge that can contribute to the multi-faceted examination of the COVID-19 outbreak and the science-based intervention processes has been increased.

COVID-19 Turkey Platform Virtual Conferences

During the pandemic in which there is a greater need for science, virtual conferences have been organized that is appropriate to the co-creation and succeeding together approach of the COVID-19 Turkey Platform. In this way, the opportunities provided by virtual environments are effectively valorized in the environmental context of the fight against COVID-19 where the power of science and technology is as strong as the mobilization of researchers. Organized virtual conferences served multiple purposes, particularly increasing scientific sharing among ecosystem researchers during the COVID-19 pandemic period, sharing experiences that are gained especially in the field of vaccination, medicine and diagnosis, encouraging open science approaches and creating social awareness and expectations. Virtual conferences have been a very important tool for science communication in order to share the developments in the scope of the science and technology-based struggle with the society and the ecosystem.

Among the virtual conferences that are coordinated by the COVID-19 Turkey Platform, the first virtual conference was held in the area of vaccines and drugs based on the “COVID-19 Turkey Platform Vaccine and Drug Development Virtual Conference” (TÜBİTAK, 2020d). Three sessions took place based on drug repurposing and drug development, innovative treatment methods and vaccine development with 14 speakers contributing to the virtual conference. Through the virtual conference, it has been possible to provide an opportunity for raising awareness on molecular docking studies based on virtual screening of drugs, in-silico studies as well as in-vitro and in-vivo processes as well as the development of drugs that will reduce import dependency with new methods of synthesis. Similarly, scientific perspectives have been presented on recombinant antibody that has a neutralizing effect against the SARS-CoV-2 virus, convalescent plasma, cytokine storm and anti-cytokine treatments for the COVID-19 disease, anti-viral approaches based on the Griffithsin

protein and its therapeutic efficacy as well as the ACE2-Fc fusion protein based protective artificial antibody. Within the scope of vaccine candidate developments, recombinant vaccine using the Spike protein of the virus, DNA and peptide vaccines, new generation COVID-19 vaccine technology based on ASC particles, preparation of a vaccine based on virus-like particles for Phase-1 clinical trials, DNA vaccine based on antigen discovery and inactive vaccine developments were shared.

The virtual conference that was livestreamed on TÜBİTAK's social media accounts was followed by 130,000 viewers with superior interest. The opportunity of allowing the questions of the viewers to be directed to the participants in a live broadcast was another development that strengthened the scientific communication between the researchers and the society.

The second virtual conference that was organized under the coordination of the COVID-19 Turkey Platform took pace in the field of diagnosis as the "COVID-19 Turkey Platform Diagnostic Power of Turkey Virtual Conference" (TÜBİTAK, 2020e). In the virtual conference, developments on medical diagnostic kits, diagnostic-oriented laboratory systems, diagnostic devices, and information and communication technology applications were addressed. There were presentation contributions from 15 firms in addition to a university researcher who developed an innovative medical diagnostic kit within a rapidly supported academic project. In this context, it was possible to gain insight on various developments on medical diagnostic kits and systems in addition to a prototype that can provide an alternative to the polymerase chain reaction (PCR) test method based on a nanomechanical system.

Through the second virtual conference, medical diagnostic kits for real-time PCR testing, digital PCR suitable for digital platforms, analysis kit, handheld smart patient diagnostic system and rapid and optimized diagnostic kits for antigen and antibody were shared with the public. Within the scope of diagnostic-oriented laboratory systems, diagnostic devices and informatics applications, a laboratory robot that makes the molecular diagnostic processes autonomous, innovative portable diagnostic laboratory, hybrid camera system for collective fever measurement, machine learning and other artificial intelligence-based solutions via ultrasonography images were shared. The second virtual conference received a total of 38 thousand 500 viewers that brought the total number of viewers of the virtual conferences with the coordination of the COVID-19 Turkey Platform in April and May to 170 thousand people.

Dissemination of Experiences in the New Normal Period

The devoted efforts that have been carried out across the ecosystem on the basis of science and technology based on an intense fight against the COVID-19 has made it possible to make significant progress to overcome the pandemic. In this process, shared wisdom was prioritized in the ecosystem

by maximizing the approaches of working together, developing together, fighting together and achieving together. There is an important opportunity to diffuse the experiences from the transformation in R&D and innovation processes that became an imperative during the pandemic period to other areas in the new normal order. Socio-economically, the effects of COVID-19 have influenced every part of society and have also increased the acceleration of digital transformation in the field of health as well as the need for food safety based on variable pressures in agriculture, food and animal husbandry (Nicola vd., 2020). It is important to expand the experiences that are gained and continue to be gained from combatting COVID-19 to areas that have gained importance during the pandemic as well as the process after the pandemic, namely the fields of biosafety, cyber security and infrastructure as well as food supply safety. These areas, each of which represent a common challenge, also play an important role in supporting sustainable development.

Biosafety in the Scope of Transformation in R&D and Innovation Processes

Biosafety, by the definition of the World Health Organization (WHO), refers to “institutional and personal security measures designed to prevent the loss, theft, misuse, diversion or intentional release of pathogens and toxins” (WHO, 2018). Although the intentional production and use of pathogens in particular is prohibited by international treaties, it cannot guarantee that they will not be used. It is important to thus identify such hazards in advance and to develop effective defense methods and technological products. Preparation for cases where living organisms or their metabolites cause intentional or unintentional mass death or damage is vital. Critical measures for the detection and protection of biological agents require technological accumulation, infrastructure and R&D studies. For example, the detection of biological agents in areas where they can pose risks, including inhaled air, agricultural areas, consumed food, water or equipment and equipment used, is possible with the development of scientific knowledge and technological devices. Such requirements can be met through the coordination of ecosystem actors with the approach of co-creating and achieving together.

Cyber Security and Broadband Infrastructure in Transformation in R&D and Innovation

Due to the measures that are implemented during the COVID-19 pandemic period, the flexibility provided by digital technologies in terms of distance and education opportunities has increased significantly internet traffic. It is stated that in OECD countries, estimated to have approximately 1.3 billion people working remotely, a 60% increase in internet traffic has occurred compared to the pre-pandemic period (OECD, 2020b). This upward trend is expected to continue due to additional measures in the new normal period post-COVID-19 in many countries. For example, the declaration of the G20 Digital Economy Ministers’ meeting in May “encourages the transition to digitalized production systems, e-commerce, digital supply of services, e-invoicing, and e-payments, and other services, as well as smart working solutions, including remote working, and innovative new business models.” This emphasis will continue to increase the intensity of the activities in the digital environment.

At the same time, cyber-attack risks increased simultaneously with increasing internet traffic in the pandemic world (OECD, 2020a). Increased phishing attacks, security of medical equipment and information, malware, physical security, remote connection /virtual private network (VPN) security and security of video conferences are especially on the agenda during the COVID-19 period. After the COVID-19 pandemic, digital technologies will continue to become widespread throughout society, from smart production to smart energy systems, and the environments where cyber security should be ensured will need to be further diversified.

Communication infrastructure is the centerpiece of today's digital age and is a critical component of the health, education, manufacturing and service sectors. It is important to have a more widespread and strong communication infrastructure to eliminate both the effects of the current pandemic situation and the new crisis scenarios that may arise in the long term and to successfully continue the digitalization steps in the country. The need to develop critical applications with local opportunities, especially in the development of fiber infrastructure, the dissemination of high-speed broadband, the creation of data centers and storage of data, and the priority technologies, such as internet of things (including internet of everything and machine to machine (M2M), cloud computing and electronic communication, stand out.

In line with the transformation in R&D and innovation processes, the development of national and unique products for cyber security, broadband infrastructure and secure 5G and beyond technologies will be continued and advanced within the scope of co-creation models.

Food Security in the Scope of Transformation in R&D and Innovation Processes

Factors that put pressure on agricultural production before the COVID-19 outbreak included food demand, climate change, soil and water resources, and urbanization factors (SBB, 2019). In addition to these factors, pressures on agricultural production was created due to different variables during the pandemic period and the importance of food security emerged once again as a social security factor. It is important to meet three basic dimensions for food security based on physical and economic accessibility, physical availability of food and sufficient quality and reliability (EIU, 2019). During the pandemic, the risks and pressures that were placed especially on accessibility and availability were managed successfully. However, the risks of similar pressures due to more permanent risks, including climate change, continue after the outbreak. For this reason, increasing agricultural productivity by using digital technologies in agriculture, including domestic seed and feed production, also with the support of biotechnology, can allow benefiting from the opportunities provided by R&D and innovation-based processes to the maximum extent for food processing, production, storage and distribution processes with the use of advanced technologies. Food supply security, which is becoming increasingly important in the global arena, is also critical during and after the COVID-19 outbreak. The initiation of an R&D and innovation mobilization that will be

gathered around the approach of co-creating and achieving together is among our priorities.

Common Challenges in the Transformation of R&D and Innovation Processes

Biosafety, cyber security and food security areas are also related to areas of importance for investment worldwide. In addition to existing investments, there are additional investment requirements for health, infrastructure and climate change in the next 20 years that are given to correspond to about 1.3% of the Gross Domestic Product per year (Gaspar vd., 2020). Similar to the ecosystem mobilization provided during the COVID-19 pandemic period, a safer and more sustainable future can be achieved by combatting for the common challenges of the ecosystem on the basis of science and technology in the new normal order.

Evaluation and Looking Ahead: Co-Creation Solutions

As part of combatting COVID-19 on the basis of science and technology, our country's experiences have been shared internationally in various environments. The ecosystem mobilization approach against COVID-19 based on science and technology, which is carried out extensively in our country, was able to involve every stakeholder of the ecosystem, unlike other approaches. At the point of evaluating the transformation that took place in the R&D and innovation processes, the approach of co-creation and succeeding together as put forward by our country has become a prominent feature. Within the scope of the European Research Area (ERA), as highlighted in the ERAvsCorona Action Plan, steps have been taken in the direction of coordination of R&D financing against coronavirus, diffusing clinical research, new funding opportunities and funding resources for innovative and rapid approaches in health, support of innovative companies, establishing a temporary high-level R&D-oriented committee, access to research infrastructures, research data sharing platform and Hackathon for entrepreneurs (EU, 2020). These steps that aim to mobilize the R&D and innovation system is not as integrated as those in the COVID-19 Turkey Platform and those for the mobilization of the ecosystem. Research areas that are emphasized by the World Health Organization (WHO) have also been put forth. These research area are epidemiological studies, clinical characterization, infection prevention and control, research on candidate therapeutics, research on candidate vaccines, ethical issues in research, as well as social science research areas in the pandemic response (WHO, 2020). Although social and humanities are among the research areas, the potential of adapting COVID-19 experiences to other challenges that require systemic challenge driven innovation is not addressed.

The R&D and innovation system, which is an important component of the social system, has undergone a multi-faceted process. After the pandemic, it is envisaged that the R&D and innovation system will enter a new normal order that internalizes the transformation in the R&D and innovation processes with

a greater focus on co-creating together. With the experiences that are gained in the pandemic period, new achievements will continue to be achieved in science-based and impact-oriented processes for other challenges that need to be resolved after the pandemic. Co-development solutions will excel to a new dimension.

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