REFLECTIONS ON THE QUADRUPLE HELIX WITH SOCIETY AND THE FUTURE OF CO-CREATING AND SUCCEEDING TOGETHER IN THE NATIONAL TECHNOLOGY INITIATIVE

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Abstract

In the context of changing, complex and dynamic processes, a quadruple helix that involves cooperation across universities, industry, public institutions and society has a key role in the success of research, development and innovation-based initiatives. The societal reflections of the National Technology Initiative in Türkiye, which is implemented with a focus of societal mobilization and societal ownership, are evaluated in this book chapter based on evaluations in three dimensions: (*i*) societal reflections of technological achievements, (ii) societal reflections on young human resources and (iii) societal reflections on solutions for complex challenges. In the first dimension, the societal reflections of domestic and national technological achievements based on a co-creation and succeeding together approach towards economic, social, environmental, and national security impacts as well as increasing societal awareness on these technological achievements are discussed. Accordingly, co-creation and succeeding together based platform developments, the Technology-Oriented Industry Move Program and the societal reflections of output and impact-oriented processes are represented. In the second dimension, the societal reflections of TEKNOFEST competitions for young talents that enter the R&D and innovation ecosystem, innovative scholarship opportunities, a research intern scholarship program, and Try-Do Technology Ateliers are covered. In the third dimension, the focus is on reflections that extend to society when addressing challenging areas of critical importance due to global risks and societal needs. As critical challenges, the global pandemic and the COVID-19 Türkiye Platform, research on mucilage, earthquake research and climate change are presented. As emphasized in the evaluation of all three dimensions, the societal reflections of the National Technology Initiative express a quadruple helix mode of ecosystem cooperation. Inclusive, holistic, transparent and interactive science approaches that focus on societal needs are increasing in importance when compared to traditional science that is far from societal needs and interactions. The societal reflections of the National Technology Initiative, which draws its strength from society and contributes to society, including technological achievements, young human resources and solutions for challenging areas have directed the future of our country to increased social welfare and sustainable economic development. In line with 2023 goals, the 100th anniversary of the Republic, and the year 2053, which is the net-zero emission target, the approach of co-creating and succeeding together with society will increasingly be continued and sustained into this future.

Keywords
R&D and innovation, Co-Creation, Quadruple helix, Society, Mobilization

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Introduction

In the success of initiatives based on research, development (R&D) and innovation, it is of utmost importance that a triple helix mode of cooperation, which expresses the interaction of universities, industry, and public institutions, extends to a quadruple helix mode of cooperation that covers society as the fourth dimension. In a quadruple helix, society should be considered not only on the demand side as merely end users of technologies but also as fundamental actors of the process that directly guides the scientific knowledge production and technology development expectations for the future of innovation systems and strengthens societal interfaces by taking part in the process (González-Martinez et al., 2021; Leydesdorff & Smith, 2022). Within the scope of citizen science, social actors become an important part of the solution, especially for difficulties related to environmental challenges and sustainable development (Skarzauskiene & Mačiulienė, 2021). Effective participation and involvement of the society in science and technology-based processes is a key aspect of building social trust and requires institutions to manage processes in a way that encourages social participation (ISC, 2021a). Taking all of this into consideration, society has an important role in the face of today's challenges, which are characterized by changing, complex and dynamic processes, requiring a quadruple helix.

An R&D and innovation based large-scale initiative, which is being carried out in Türkiye as the National Technology Initiative, involves an approach that covers all the actors of the ecosystem and ensures that it is embraced by society, putting forth a prominent example of quadruple helix cooperation. The Technology-Oriented Industry Move Program, which has an important place in terms of the economic and technological independence as the 100th anniversary of the Republic is approached, is being implemented with the social ownership and mobilization of human resources of all ages, from seven to seventy, in the focus of societal mobilization (STB, 2019). In this context, it includes sharing domestic and national technological achievements with society, involving young human resources in technology development processes, and strengthening the mobilization of society with a dedicated focus on a strong Türkiye that actively innovates in technology (STB, 2019). The societal reflections of the National Technology Initiative, in which societal mobilization plays a key and central role at the level of a large-scale national initiative, can be similarly defined multidimensionally involving three main dimensions.

The first of three main dimensions of the societal reflections of the National Technology Initiative and the future of the country that is discussed in this book chapter involves the awareness that is created in society for domestic and national technological achievements with a focus of co-creation and succeeding together approach. The second main dimension is based on an inclusive approach for involving young human resources and their talents with an active participation in the R&D and innovation ecosystem. Next, the third main dimension represents the approaches that strengthen the mobilization of the ecosystem in addressing global challenges and societal needs that directly extend to society. In this context, by focusing on (*i*) societal reflections of technological achievements, (*ii*) societal reflections on young human resources, and (*iii*) societal reflections on solutions for complex challenges, this book chapter provides an evaluation of the three main dimensions respectively. Each dimension is evaluated by emphasizing the importance of quadruple helix cooperation. Based on the National Technology Initiative, the key importance of a quadruple helix for the sustainable future of the country is revealed.

Societal Reflections of Technological Achievements

The National Technology Initiative is strengthened by a strategic approach that focuses on developing critical technologies and increasing independence in high technology areas. This strategic approach is based on a "co-creation and succeeding together" approach that activates different competencies in the R&D and innovation ecosystem interactively and enables new synergies (Mandal, 2022). This approach is supported with management processes that are oriented on outputs and impacts. The national co-creation models provide significant impact potential in terms of economic, social, environmental, and national security, and these important technological achievements have important societal reflections.

Co-Creation and Succeeding Together Platforms

High Technology Platforms have a central place in the co-creation-based models of our country. These platforms ensure the implementation of Strategic Research Programs by bringing together research universities, research infrastructures, private sector R&D or design centers, and public R&D units for a common high technology goal. In the first 8 High Technology Platforms where Strategic Research Programs are implemented, 23 companies, 19 universities, 4 research infrastructures, and 2 public R&D units execute the research programs, bringing together the ecosystem for technological achievements (TÜBİTAK, 2022f). Among these platforms, those that will have an impact on healthy life involve 5 platforms that focus on regenerative and restorative medicine research and applications, target-specific pan-cancer therapies, nanotechnological sensors, functional surfaces, biochips and biocompatible active and integrated systems, diagnostic kits against HPV and influenza-borne infections, drug formulations and vaccines, biomarkers, and biotechnology drugs for treating auto-inflammatory diseases. In those platforms that focus on high technology contributions in terms of competitive industry and clean energy, these focus on high-efficiency and silicon-based solar cells, including advanced materials, avionic display technologies, new generation 3-D printing technologies and manufacturing. In each of the areas covered by these platforms, the focus is on realizing the impact potential, taking into account the social benefits to be provided by high technologies developed according to technology development roadmaps.

Industry Innovation Networks, which are another form of co-creation-based platforms, involve a total of 41 firms, 18 of which are small and medium-sized enterprises (SMEs) and 23 are large-scale organizations, 18 universities, and 5 research centers that have come together in the first 4 platforms. In these platforms where Strategic Product R&D Programs are supported, the product-oriented roadmaps involve 87 projects that are implemented on smart home products, smart cities, additive manufacturing and health products (TÜBİTAK, 2022f). Based on the approach of co-creation and succeeding together, each platform has a high impact potential. Accordingly, it becomes essential to increase societal awareness on these developments in the ecosystem. In the High Technology Platforms and Industry Innovation Networks that will be newly supported, priority is given to co-creation-oriented formations that will contribute to addressing climate change, circular economy, clean energy, smart transportation and sustainable agriculture as priority areas for R&D and innovation in line with the European Green Deal.

Technology-Oriented Industry Move and Company Visits

In the Technology-Oriented Industrial Move (HAMLE) Program, which is the most critical program of the National Technology Initiative, the domestic and national production of 919 critical products are being targeted to prevent the import of 50 billion dollars (STB, 2019; Duran, 2022). In this program, which extends from the R&D phase to the investment phase in an end-to-end approach, the first pilot call for producing high value-added, medium-high and high technology products with domestic and national resources prioritized the machinery sector. Of the 20 machinery sector projects that were supported in this program (STB, 2021), 11 machinery sector projects involved R&D and innovation needs with the R&D and innovation expenses covered by TUBITAK. Through visits to these companies as an important element of the National Technology Initiative, societal awareness is raised on technology-based breakthroughs that industrial actors are making in the ecosystem for domestic and national production.

Accordingly, the medium-high and high-tech products that are developed in various sectors by the 11 companies that receive R&D and innovation support under the machinery sector call of the HAMLE Program have been visited. These companies are producing machinery equipment and sub-products that are important for domestic and national production, including innovative additive manufacturing technology based on laser additive manufacturing with automatic powder circulation that is important for the aerospace, defense and health sectors. Other examples involve thin-walled ball bearings for applications requiring precise positioning in the defense industry, 100% domestic robots and their sub-components, and synchronous electric drive system servo motor, which is a critical component in the civil and defense industry. In addition, diesel or alternative fuel internal combustion engines, the production processes of oil and fuel filters in these engines, and supercritical water oxidation reactor are being developed by industrial actors. Image processing software and automation machines, providing full automation of electrical cable production, that is especially used in the automotive, white goods and informatics industries, has been produced. Elevator technologies that are compatible with smart buildings, reducing energy consumption with a regenerative system, and have innovative software and hardware, such as hygienic recognition, are among the examples (STB, 2021). In the newest calls of the HAMLE Program, a total of 91 R&D project applications in the mobility call, 41 R&D project applications in the structural transformation in production call, 105 R&D project applications in the health and chemical products call, and 117 R&D project applications in the digital transformation call have been received for a total of 354 R&D project applications in these other prioritized sectoral calls.

Output and Impact Oriented Process Management and Society

As a new evaluation implemented in the scope of output and impact-oriented process management, a Commercialization Monitoring Process is established for each technology and innovation-oriented project (TÜBİTAK, 2021c). This process ensures that output and impact-oriented process management continues after the completion of the support period for technology and innovation-oriented projects. This practice is beneficial for monitoring and observing the impact of R&D and innovation on society.

Among the various opportunities that have been increased with a focus of output and impact, the Patent-Based Technology Transfer Support Call supports the transfer of patented technologies developed in universities, research institutions and technology development zones to the industry to make an impact (TÜBİTAK, 2022d). In this context,

43 projects were supported in the first 3 calls, including the cooperation of 31 different technology providers and 39 different customer firms for the licensing of 51 patents. These patents, which are being transferred to the industry, include different technologies that contribute to competitive industry, health, clean and efficient energy and innovative food products. For example, those that contribute to a more competitive industry include technology to encrypt big data with less cryptographic processing, multi-layer hybrid and functional grade composite material, and innovative drone wings. Those technologies that are transferred to the industry and serve healthy life involve ASC granular cancer vaccine, biomarkers for the diagnosis of Alzheimer's disease from gut microbiomes, and organic bioactive materials for dental and orthopedic implant surfaces. Technologies serving clean and efficient energy include battery integrated concentrated solar panel with active tracking system and innovative wind turbine technology. It is also possible to give examples for technologies serving innovative food products based on innovative food products containing natural protein and collagen and nanotechnological food packaging material that extends shelf life. The societal reflections of these processes extend to society based on the technological advances turning into impacts.

Societal Reflections on Young Human Resources

Raising young human resources who actively take responsibility for the future in line with the National Technology Initiative and finds solutions to important needs with a focus on co-creation is a strategic value that strengthens the ecosystem. When the key skills that are important for the jobs of the future are considered, technology design and programming, critical thinking, systems analysis and evaluation skills take place among the top 10 skills. In addition, skills for innovation, active learning, creativity, originality and taking initiative, complex problem solving as well as leadership and social impact are included (WEF, 2020). Other skills have come to the forefront based on the changing, complex and dynamic processes that escalated in the global pandemic period. For example, the ability to perceive and act quickly with agility and flexibility, the ability to overcome challenges and develop strategies through continuous improvement and learning, the ability to work together as a team member through teamwork and cooperation, and the ability to identify and anticipate changes in the environment to adapt to dynamic processes are essential (Lieberman, 2021). In this context, a profile of expectations can be drawn that combines scientific and technological competencies with teamwork, who can respond to the critical needs of the future, and can act to meet the needs of changing, complex and dynamic processes.

Young Talents at the Aerospace and Technology Festival

The energy of the young human resources reflects to the National Technology Initiative by ensuring that talents for technology development engage and compete within focused teamwork at the level of the TEKNOFEST Aerospace and Technology Festival. In this scope, TEKNOFEST is held in the Black Sea for the first time with a festival in Azerbaijan taking place between May 26-29, 2022 and Samsun during August 30 - September 4, 2022. With a focus on independence and a strong Türkiye, competitions are organized with a focus on jet engine design, model satellites, robotics, artificial intelligence in health and transportation, new agricultural technologies, and environment and energy technologies (TEKNOFEST, 2022). TÜBİTAK participates as an organizer or organizing partner in 15 out of 40 different competitions, ensuring the implementation of the projects of young human resources in the fields of unmanned aerial vehicles (UAV), electric vehicles, autonomous vehicles, rocket development, biotechnological innovation, polar research,

and other fields. There are also University Students Research Project Competitions consisting of 9 categories, namely machinery, manufacturing and automotive, defense and aerospace, health, food and agriculture, energy and environment, smart cities, information and communication technologies, and education, social innovation and entrepreneurship. Solution-oriented scientific and technological skills of young human resources are also encouraged with the Climate Change Research Projects Competition, Hyperloop Development Competition, Vertical Landing Rocket Competition, and Life Technologies without Disabilities held for the first time in 2022.

Through the International UAV Competition, awareness on UAVs is increased and disseminated among pre-university, undergraduate, and graduate students where teams contribute to mastering the technological developments and compete in the categories of rotary and fixed wing UAVs. A total of 660 teams, 290 teams in the rotary wing category and 370 teams in the fixed wing category, applied to the 2022 International UAV Competition (TÜBİTAK, 2022c). In the International Free Mission UAV Competition, different types of UAVs, such as hybrid and flapping wing in addition to rotary wing and fixed wing types compete without a category and task description. Applications for this competition were received from 382 teams consisting of high school and equivalent school students and pre-university, undergraduate and graduate students (TÜBİTAK, 2022c). A total of 1252 teams applied in the rotary and fixed wing categories in the Inter-High School UAV Competition, which is only for high school and equivalent school students. These numbers are an important indicator of the curiosity and desire to develop technology that is aroused in young human resources for high technologies and is another achievement of the National Technology Initiative as societal reflections. Through TEKNOFEST competitions, technology-oriented teamwork skills of young human resources improve significantly.

The International Efficiency Challenge Electric Vehicle Races are organized to advance the technology development skills of young human resources for electric and clean fuel vehicles, which are an important option in energy systems based on renewable energy sources. In these races, in which pre-university, undergraduate and graduate students participate, technical, professional and teamwork experience is gained beyond the awareness of alternative and clean energy sources. A record number of 120 teams, 102 teams in the electromobile category and 18 teams in the hydromobile category, applied for the 2022 International Efficiency Challenge Electric Vehicle Races (TÜBİTAK, 2022b). This excitement is also reflected in the High School Efficiency Challenge Electric Vehicle Races. Applications from 250 teams were received for these races, which are open to high school students from Science and Art Centers, Youth Centers, Try-Do Technology Ateliers, Science Centers, and high school students from Türkiye, Azerbaijan, and the Turkish Republic of Northern Cyprus. These races, which mobilize young human resources for the development of electric vehicles, also contribute towards shaping an environmentally friendly future in which green technologies are an important driving force. In this respect, it is also important for the green development revolution of the country (Ministry of Communication, 2021).

Innovative Scholarship Opportunities for Young Human Resources

Another important opportunity for raising qualified young human resources who will contribute to the co-creation and succeeding together approach of the ecosystem is the Industrial Doctorate Program. The Industrial Doctorate Program is established in a unique way to raise human resources with doctorate degrees based on university-industry

cooperation in the fields demanded by the industry and encouraging the employment of researchers with doctorate degrees in the industry for technology development, raising 1,162 scholars to date. Both scholarships and employment support for 3 years after graduation are provided to the scholars who are raised in 308 cooperation projects carried out by 49 different universities with 210 different industrial firms (TÜBİTAK, 2022f). Industrial Doctorate scholars are educated in various fields, including electrical and electronic engineering, mechanical engineering, materials science and engineering, industrial engineering, computer science, artificial intelligence, energy, chemical engineering and technology as well as biotechnology and life sciences. According to the demands of the industry, scholars contribute to the industry's entry into new areas, strengthen existing industrial areas, achieve new technological achievements, and even support becoming a patent champion in newly developing technological areas (Patent Effect, 2022). This program is also important for the sustainability of the co-creation approach in the R&D and innovation ecosystem. A significant part of the ecosystem actors that collaborate in the Industry Doctorate Program are also involved in the co-creation models of High Technology Platforms and Industry Innovation Networks, thereby providing a multiplier effect for output and impact-oriented process management.

Another innovative scholarship program of TÜBİTAK is the scholarship program named for the Nobel Prize-winning scientist Prof. Dr. Aziz Sancar. This program focuses on developing co-creation oriented human resources under his academic advisership and is opened for young human resources with a doctoral degree or specialization in medicine who are given the opportunity to undertake postdoctoral research studies with Prof. Dr. Aziz Sancar in his research laboratory (TÜBİTAK, 2022a). Moreover, in response to young human resources who are emphasizing "we are here" as researchers at all levels of education and research careers, the calls of the Intern Researcher Scholarship Program (STAR) focus on undergraduate students. In its first two calls, 3,043 undergraduate students were included in research projects supported by TUBITAK or conducted at TUBITAK Centers and Institutes. Within the basic sciences, engineering, health and social sciences, research projects that are focused on computer engineering, electrical and electronic engineering, molecular biology and genetic engineering come to the fore (TÜBİTAK, 2021b). The new STAR calls continue to allow undergraduate students to take part as intern researchers in the R&D and innovation ecosystem. 2,300 undergraduate students are targeted, including students in archeology and the protection and restoration of cultural assets. This call involves the partnership of the Ministry of Industry and Technology, the Ministry of Youth and Sports, and the Ministry of Culture and Tourism. Archeology scholars are given the opportunity to conduct research with world-renowned scientists at the ancient ruins of Göbeklitepe in Şanlıurfa (TÜBİTAK, 2022e).

Future Technology Stars and Societal Reflections

The National Technology Initiative covers all segments of the society and extends to all age groups and future technology stars. With the target of establishing Try-Do Technology Ateliers in 81 provinces by the year 2023, a total of 66 ateliers in 55 provinces and more than 12.000 students are being trained as young human resources who try, question, produce and develop the technologies of the future. Future technology stars learn by doing in design and production, robotics and coding, electronic programming and internet of things, software technologies, advanced robotics, aerospace technologies, energy technologies, nanotechnology and materials science, artificial intelligence and cybersecurity in alignment with the professions of the future (Deneyap Türkiye, 2022). Beyond the Try-

Do Technology Ateliers that are important for sustaining the National Technology Initiative for future generations, various science and society support programs and activities reach approximately 18 million people (TÜBİTAK, 2022f). The number of Science Centers to disseminate scientific culture in society is also increasing (TÜBİTAK, 2022h). After the first thematic and 6th science center of Bursa Gökmen Aerospace Training Center, new science centers in Antalya, Gaziantep, Şanlıurfa, Düzce, and Denizli are being established.

Societal Reflections on Solutions for Complex Challenges

The mobilization of the R&D and innovation ecosystem is a prerequisite for science and technology-based solutions in the face of complex challenges, such as the pandemic, natural disasters, and climate change (Mandal, 2020). The complexity of these challenge areas is too broad for a single discipline or industry to solve alone. Considering the global risks, extreme climate events and infectious diseases stand out based on likelihood and impact (WEF, 2021). There are also interactions between different global risks. For example, inadequate action against climate change, anthropogenic environmental damage and loss of biodiversity are known to be global risks that are highly interdependent with one risk triggering another. From a one health perspective, these risks also have interactions, especially with infectious diseases. In contrast, other interactions among global risks involve difficulties in living conditions and other impacts of climate change at the societal level, such as forced migration (WEF, 2022). Interconnected risk clusters has clearly made it necessary for scientists and the professional business world to come and work together to reduce risks and for the society to learn from each other (Future Earth-ISC, 2021). For all of these reasons, the approach of co-creation and succeeding together, which is applied as a strategic approach, has special societal reflections for these challenge areas.

Mobilization of the Ecosystem Against the Pandemic

Providing direction to pioneering breakthroughs globally, applying agile and adaptable approaches to innovation, and increasing global competitiveness are important priorities (STB, 2019). In this context, taking into account global risks, the R&D and innovation ecosystem has been mobilized to strengthen the provision of science and technology-based solutions through the National Technology Initiative to address the pandemic, natural disasters, and climate change. Before the pandemic was declared, 436 researchers from 49 institutions in the ecosystem were mobilized with a co-creation and succeeding together approach under the COVID-19 Türkiye Platform for the development of vaccines and drugs (Mandal, 2021b). Virtual conferences that were held during the development process of vaccine and drug candidates ensured that developments were shared with society in a transparent manner while also involving an interactive process of openly informing as well as answering the questions of society. In this respect, transparency and cooperation are counted among key factors in effectively accelerating the R&D and innovation processes against the pandemic (WHO, 2020). The clinical phase studies for the vaccine and drug candidates of the COVID-19 Türkiye Platform also involved active societal participation as an important societal reflection. The virus-like particle (VLP) vaccine candidate involved 38 volunteers in Phase 1, 349 volunteers in Phase 2, and 600 volunteers in the advanced Phase 2B studies. In addition, clinical phase studies in innovative inactivated and vector-based adenovirus vaccine candidates were made possible with societal participation (TÜBİTAK, 2022i). Clinical phase studies were also conducted in drug candidates, including Montelukast, which was identified based on the virtual screening of 20,000

molecules. Apart from vaccine and drug developments, the call for social sciences and humanities focused on "COVID-19 and Society" examined the social, economic and human impacts of the pandemic, supporting 97 research projects directed towards creating impact for a healthier society. The projects covered such fields as education, economics, business, mass communication and tools, architecture, urban and regional planning, psychology, health, political science, public administration, and sociology. The project results were shared transparently with societal stakeholders (STB-TÜBİTAK, 2021) as another means of strengthening the science-society interface.

Multidisciplinary Mucilage and Earthquake Research

As an environmental challenge, mucilage jointly triggered by environmental pollution and climate change, required technological solutions and awareness raising for the prevention of marine pollution (MMB, 2021). In this context, reaching society through citizen science as well as multidisciplinary and transdisciplinary research on examining the social effects of mucilage have played an important role. The Mucilage Research Special Call focused on investigating the effects of mucilage on biodiversity, increasing restoration studies, revealing the formation mechanisms of mucilage, reducing the pollutants entering the marine environment, the disposal of mucilage, analyzing the effects of mucilage on public health and socioeconomic aspects. Under this special call, 37 projects involving 153 researchers from 31 different institutions came together to create domestic and national solutions (TÜBİTAK, 2021a). The supported projects provided solutions to prevent mucilage formation from its source, the detection and tracking of mucilage with multiple satellite sensors, oceanographic early warning systems for mucilage, and assessment of integrated effects on blue economy sectors, such as maritime transport and fishing activities. As represented in Figure 1, multidisciplinary and transdisciplinary research that can meet the needs of complex challenges is of particular importance. Here, the interactions of science, engineering, and social sciences and humanities are presented for 37 projects. Out of 37 projects, 10 projects bring together the basic sciences, engineering, and social sciences and humanities. As a means of creating science-based awareness in society about the mucilage research projects under this special call, researchers further met with societal stakeholders in a 5-session virtual event, sharing their results.

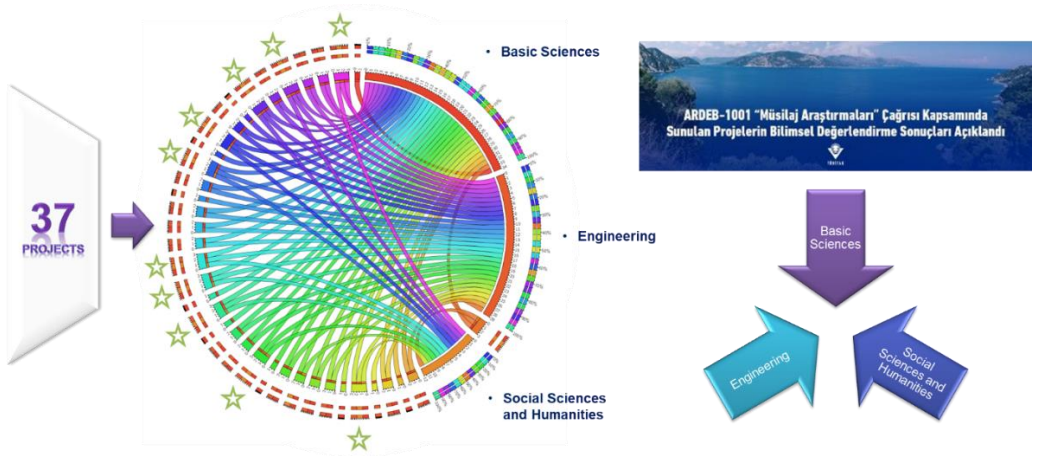

Figure 1. *Depiction of multidisciplinary and transdisciplinary research in the special call for mucilage research*

Another area where the mobilization of the R&D and innovation ecosystem is critical due to the geographical location of the country is earthquake research. Considering disaster management against natural disasters, increasing science and technology-based solutions both prior to, during, and after the disaster becomes important (JRC, 2017). In this context, the Earthquake Research Call was launched with a multi-faceted focus on thematic areas, namely earth science research, comprehensive scenario development, prediction and analysis studies, digital technologies for earthquake engineering, robotic systems for search and rescue activities, innovative construction and advanced material technologies, engineering solutions for architectural designs, and an analysis of the socio-economic impact of earthquakes. In total, 80 projects were supported with a focus on science and technology based solutions and social impacts (Mandal, 2021a). Among these projects, the co-creation and succeeding together approach towards earthquake research was expanded in 19 jointly coordinated projects with common goals and objectives. The distribution of basic sciences, engineering, social sciences and humanities for the 80 projects of the Earthquake Research Call and 19 coordinated projects is represented in Figure 2.

While the ratio of projects covering all three areas of basic sciences, engineering, social sciences and humanities is 18% in the call overall, such a ratio for coordinated projects takes place as 48%. The supported projects include the development of an Earthquake Scenario Simulation Platform to increase urban resilience by coordinating across the earth sciences, earthquake engineering, civil engineering, urban and regional planning. To prevent or reduce the physical, economic, social, environmental and political damages and losses that may be caused by earthquakes, other examples focus on resilient, safe and prepared cities, effective engineering solutions for earthquake resistant and earthquake-damping architectural designs, satellite and on-board sensor data for risk management. Drone routing models are among other innovations in the supported projects. In the virtual conference of the Earthquake Research Call that was organized to share the project developments transparently, active interaction between researchers, society and relevant institutions were further ensured in 11 different sessions. Researchers come together from 41 different universities and research institutes, including a variety of disciplines from geological engineering, computer engineering, communications engineering, geological surveying and mapping, civil engineering, public administration, psychology, sociology, and educational sciences.

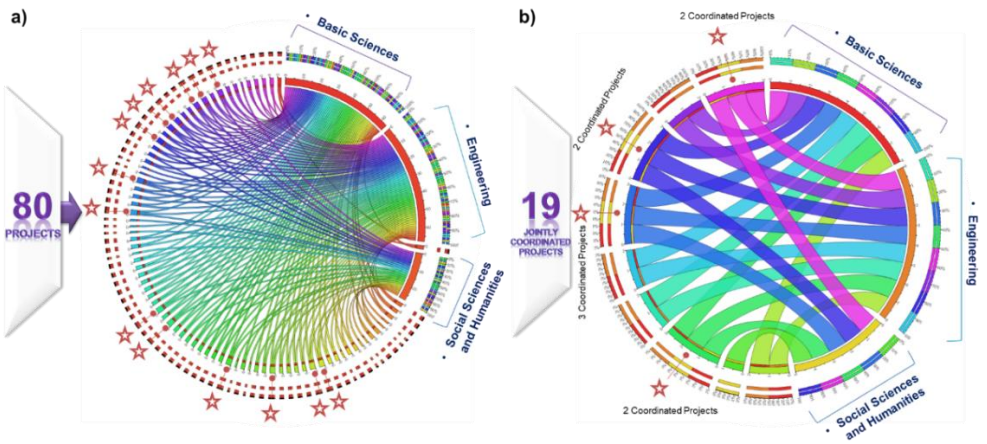

Figure 2. *Depiction of the fields of all projects (a) and coordinated projects (b) in the earthquake research call*

Society in Climate Change and Challenge Areas

Climate change as a critical challenge requires transformations at all levels of social systems (IPCC, 2022). To avoid exceeding global warming of 1.5°C above pre-industrial levels, which is accepted as a critical threshold value for climate change, it is essential to reduce greenhouse gas emissions with a rapid, comprehensive, and continuous trend (IPCC, 2022). As the widespread effects of climate change extend to the ecological balances and integrity of ecosystems worldwide, reducing the unsustainable pressures of society on natural systems through more efficient systems have become an urgent need. In this context, 170 academic projects and 34 projects of SMEs were supported in the first calls of TÜBİTAK in priority R&D and innovation areas in alignment with the European Green Deal. These projects involved a wide array of possibilities for the development of innovative energy storage, lithium-ion batteries, grid-connected battery energy storage, perovskite solar cells, high-performance wind power generation prediction models, circular economy solutions considering water-energy-food-ecosystem interactions, catalytic methods and membranes utilizing green chemistry, nanoplastics and nanocomposite recovery, biochar for soil quality, and UAV and satellite systems in agriculture. Moreover, under the Entrepreneurship Support Program (BiGG) where a total of 1948 entrepreneurial companies have been supported, 45 new entrepreneurs are supported in the first thematic call focused on Green Growth to realize their green growth-oriented business plans (TÜBİTAK, 2022g). In the scope of the Green Transformation Move and the net-zero emissions target for 2053 of Türkiye, 34 technology-based policy proposals of the Science and Technology Commission were also accepted in the Climate Council decisions. A proposal that cross-cuts all technology-based policy proposals horizontally aimed at strengthening ecosystem mobilization in combating and adapting to climate change. Holistic steps are being taken across R&D, human resources, technology entrepreneurship, co-creation oriented platforms, joint use of research infrastructures, finance, society, and other complementary facilitation mechanisms.

Considering the complexity of challenge areas, the transition from traditional science to the necessary science that can meet the needs of the 21st century can only be achieved through the transformation of R&D and innovation processes (ISC, 2021b). The characteristics of traditional science are that disciplinary with the dominance of sectoral distinctions is far from societal needs and interactions. Other features of traditional science involve fragmented approaches that cannot be combined and shortcomings in contributing to common goals. In contrast, the science that is necessary to meet the needs of the 21st century, especially climate change, is inclusive, integrated and open with a societal needs-orientation and effective interactions visibly taking place. From this perspective, the necessity of science-based and comprehensive approaches and multidisciplinary contributions to common goals are defining features with main emphasis on inclusiveness, holistic approaches, transparency and interaction. These keywords are also central aspects of the co-creation and succeeding together approach that is well-represented in the societal mobilization of the National Technology Initiative. In the research landscape scenarios for the coming years around the world, scenarios involving open science, collaboration and technological transformation (Elsevier, 2022) will also be more effective for challenge areas. There is a trend towards sustainability-oriented innovation systems where the ecosystem meets common goals (Kılkış, 2016).

Conclusion: The Future of Quadruple Helix Cooperation and Society

Reaching the year 2023, the 100th anniversary of the Republic of Türkiye, ensuring independence in critical technologies with a focus of domestic and national technologies and the development of environmentally friendly green technologies that will contribute to a sustainable future has strategic importance. In the process of creating impact for increasing social welfare and sustainable economic development in the scope of the realization of the National Technology Initiative (STB, 2019), a quadruple helix cooperation with society has importance for societal mobilization and ownership. These aspects, which are considered as the societal reflections of the National Technology Initiative, have been examined comprehensively in this book section within the scope of (*i*) societal reflections of technological achievements, (*ii*) societal reflections on young human resources, and (*iii*) societal reflections on solutions for complex challenges. As emphasized in these evaluations, the societal reflections of the National Technology Initiative are among the basic elements of the mobilization of the R&D and innovation system with focus on a co-creation and succeeding together approach. The success of bringing together universities, industry, public institutions and society in synergy with quadruple helix cooperation is possible through the active contribution and interactions of societal stakeholders as an ecosystem actor. The mobilization of the ecosystem will continue to be critical in achieving a more sustainable future with domestic and national technologies based on the 2053 net-zero emissions target of Türkiye. The social dimension of the National Technology Initiative is in a strategic position, and the approach of co-creating together with society and succeeding together with society will increasingly continue forward.

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Prof. Hasan Mandal attained his Ph.D. 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, 75 in SCI journals, an h-index of 22, 1740 citations, and 6 international patents, Prof. Mandal holds various national and international awards, including the TÜBITAK Science Award. He is a member of TÜBA, World Academy of Ceramics, and Academia Europaea. Prof. Mandal was appointed as a member of the 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 TÜBITAK 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 on November 1, 2018. He was elected as a board member of the Council of Higher Education in April 2019. The second term of Prof. Mandal as the President of TÜBİTAK through appointment commenced on February 21, 2022.