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0.1 What is science in a transforming society? What is technology? What is innovation?

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Abstract

Attention has long been drawn to the need for evidence-based policy creation, as well as the need for a "science of science, technology and innovation policy" to serve as the foundation for science, technology and innovation policy. In Japan, a project to promote "science for policy" in science, technology and innovation policy was launched in 2011. This project is underpinned by the recognition of the fact that science, technology, and innovation are changing with our society, as are the target, scope, and purpose of science, technology, and innovation policy. This paper provides an overview of the need for evidence-based policy creation, with a focus on the following questions:

- What is the interface between science, technology and innovation and society?
- What social challenges and risks do we currently face?
- What are science, technology, and innovation? What is changing and how?
- What role is science, technology and innovation policy expected to play?

Keywords

Science, technology, innovation, science, technology and innovation, social issues, Budapest Declaration

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Changes in the environment surrounding science and technological innovation[3]

The acceleration of globalization since the end of the twentieth century, the dramatic development of digital technology, and the emergence of global issues like climate change have transformed the political, economic, and social systems, values, and lifestyles of modernity (Arimoto, Tateo, 2015). Along with the globalization, openness, and digitalization of the economy and society, similar changes are occurring in the arena of science, technology and innovation, with the structure itself becoming more complex.

According to the 1999 Budapest Declaration (World Declaration on Science and the Use of Scientific Knowledge, adopted on July 1, 1999), science should play four roles: science for knowledge, knowledge for progress; science for peace; science for development; and science in and for society.[4] Now, nearly twenty years after the Budapest Declaration, it is necessary to question how science, technology and innovation activities and the relationship between science, technology and innovation and society have changed.

The multilayered nature of the interface between science, technology and innovation and society

It is necessary to understand the multilayered nature of the interface between science and technology and society. Certainly, beyond the creation of knowledge, science and technology are expected to contribute to the resolution of social issues and the creation of innovation. For example, the UN's 2030 Agenda for Sustainable Development (SDGs: Transforming our world: The 2030 Agenda for Sustainable Development) expects science, technology and innovation to play a role in achieving its goals.[5] Meanwhile, terms like "Innovation Imperative" and "Innovation for Growth" are used to describe the mobilization of science and technology to facilitate innovation, which is expected to lead to the growth and development of society (e.g., OECD, 2018).

However, the development and social diffusion of science and technology produces new social issues. Various social issues that become apparent with the spread of science, technology and innovations, such as the impact of the introduction of AI on employment, privacy issues associated with the use of big data, and the need to consider the safety and ethical aspects associated with genetic modification and gene editing, as well as the legal developments in response to these issues. These are known as ethical, legal, and social issues (ELSI).[6]

Moreover, rather than existing separately, science and technology are becoming increasingly embedded in society. The direction of the development of science, technology and innovation is becoming increasingly

3 The definitions of science, technology, innovation, and science, technology and innovation are discussed hereunder.

4 http://www.unesco.org/science/wcs/eng/declaration_e.htm;http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu4/siryo/attach/1298594.htm; http://pari.u-tokyo.ac.jp/publications/column10.html

5 Science, technology, and innovation policies and the SDGs are discussed in 0.1.1.

6 ELSI is discussed in 3.1.1.

connected with the foundations of society—including infrastructure, social design, and democracy—as well as with the transformation of society, individual values, and the way in which we work and live. It is no longer possible to understand society without understanding science and technology, or apply science and design technology without understanding the role of science and technology within society (Bijker, 2006).

At the same time, there are questions facing society (e.g., trans-science)[7] that can be asked of science, but cannot be answered by science alone. The need to deepen our understanding of these issues has become apparent through incidents like the Fukushima Daiichi Nuclear Power Plant accident in March 2011.

Amid the increasingly inter-disciplinary nature and complexity of issues involving science, technology and innovation and growing importance of the involvement of various non-governmental actors, the concept of "governance" is required to encompass and coordinate such issues. Governance is the design of functions, mechanisms, and institutions for social decision-making, with an eye to forging a horizontal relationship between traditional government and organizations involving a wide range of government and non-government actors[8].

Based on the multi-layered nature of the interface between science and technology and society described above, discussions and efforts are being made on how society as a whole should direct and accept research and innovation, and the direction in which direction society should evolve. In Europe, the concept of responsible research and innovation (RRI) has been under development since the 2010s, not only from an ethical perspective, but as an approach to appropriately position science, technology and innovation within society and promote inclusive and sustainable research and innovation design. In this context, efforts are being made to cultivate a research field based on 1) gender equality, 2) science literacy and science education, 3) public engagement, 4) open access, 5) ethics, and 6) governance[9].

Japan's Fifth Science and Technology Basic Plan[10], described below, similarly extols the need for collaboration and co-creation by various stakeholders based on the premise of the close connection between science and society.

> The history of humanity has been rewritten by the interaction between science and technology and social systems, the relationship between the two growing ever closer with the rapid advance of science and technology. In what could be called an era of great change, dialog and collaboration between diverse stakeholders are essential to taking the first steps toward creating future industries and social reform through science, technology and innovation, and addressing economic and social challenges. Therefore, it is necessary to deepen the conventional relationship positioning science and technology as relative to society to forge a relationship that promotes dialog and collaboration, that is, "co-creation" among a variety of stakeholders, including researchers, the public, the media, industry, and policymakers.
> (Chapter 6)

7 Trans-science is discussed in 2.2.3.

8 Science and technology governance is discussed in Chapter 2.

9 https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation

10 https://www8.cao.go.jp/cstp/kihonkeikaku/index5.html

An overview of social issues

Given its multi-layered nature, in considering the position of science, technology and innovation within society, it is worth introducing examples of recognized social issues and risks we currently face.

The UN SDGs described above are global issues that the international community should come together to address. In this respect, the UN agenda sets seventeen goals[11] as important guidelines for the international community to eradicate poverty and achieve a sustainable society by 2030 through the harmonizing of three key elements—economic growth, social inclusion, and environmental protection—based on the principle that "no one will be left behind." The agenda recognizes a diverse set of social issues, as illustrated below.

Social issues covered by the SDGs:
Ending poverty and hunger; ensuring food security; improving nutrition; practicing sustainable agriculture; ensuring healthy livelihoods; promoting welfare; providing inclusive, equitable, and quality education; promoting gender equality; ensuring access to and the sustainable management of water and sanitation; ensuring access to sustainable and modern energy; facilitating sustained, inclusive, and sustainable economic growth; providing productive and full employment and decent work; ensuring resilient infrastructure development; increasing innovation; reducing inequality within and between countries; developing inclusive, safe, resilient, and sustainable cities and settlements; ensuring sustainable patterns of consumption and production; addressing climate change; ensuring the sustainable development and use of oceans and marine resources; protecting, restoring, and promoting the sustainable use of the earth's ecosystems; promoting the sustainable management of forests; combating desertification; halting biodiversity loss; promoting peaceful and inclusive societies; providing access to justice for all; building effective, responsible, and inclusive institutions at all levels; and revitalizing global partnerships.

Other examples of important contemporary issues that need to be solved, mega-trends affecting science, technology and innovation, and more local social issues include:

Important issues that need to be solved:
Addressing the demographic challenges of the twenty-first century, including population growth, migration, and ageing; simultaneously addressing issues of water resources, energy, food and climate; responding to changing geo-economic and geopolitical landscapes; addressing moving frontiers (i.e., how digitalization is driving economies and changing the way we work); and addressing global-scale imbalances in wealth, health, and knowledge (OECD, 2016a).

Megatrends shaping science and technology innovation:
Population, resources and energy, climate change and environment, globalization, the role of government, economy, employment and productivity, society, health, inequality and welfare (OECD, 2016b).
Examples of local social issues:

11 For details, see 0.1.1 and https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Weakening personal connections, children's environments, growing self-centered behavior, diversifying and heinous crime, declining town functions, insecurity in the lives of the elderly, insecurity of the sustainability of medical services, misalignment between work and family life, tapering of human resources, deterioration of working environments, concern regarding the distribution of wealth, disparity in rural areas, insecurity about new systems, environmental disasters in urban areas, insecurities arising from terrorism and infectious diseases, food and everyday goods insecurity, and transboundary environmental pollution (JST-RISTEX, 2010).

Moreover, international organizations (e.g., UNESCO, 2015), national governmental organizations (e.g., the National Intelligence Council, 2012, USA), and even industry bodies (e.g., Eurasia Group, 2017) are tackling social issues and risks with a view toward future society.

In light of the foregoing, it is clear that many of the currently recognized global and local social issues are in some way related to science, technology and innovation, both positively and negatively. These are issues that need to be solved by science and technology or, conversely, issues produced by new science and technology, or social problems that can be asked of science and technology but cannot be solved by science and technology alone.

What is science? What is technology? What is innovation? Definitions

Let us review the definitions of science, technology, innovation, and science, technology and innovation. This section introduces aspects of each of these dimensions that appear to be changing.

Science

Science is the creation of knowledge through the process of hypothesis formation and testing. However, there are many other definitions. For example, after introducing the definition of science proposed by Thomas Kuhn and Carl Sagan, Neal et al.'s (2008) seminal textbook on science policy in the US asserts, "Science is used to describe both processes and outcomes. In other words, it is the process of obtaining knowledge and the obtained knowledge itself."

Technology

Technology is defined as a means and method for achieving an objective.

Innovation

Innovation is the social transformation produced through new combinations of knowledge. Schumpeter defines innovation as "new combinations of new or existing knowledge, resources, equipment and other factors."[12]

12 For more information on what innovation is, see 1.0.1.

Science, technology and innovation

"Science, technology and innovation" is a policy term. In respect to its definition in policy documents, the Science and Technology Basic Plan defines science and technology and scientific and technological innovation as "the creation of intellectual and cultural value based on new knowledge produced through scientific discoveries and inventions, and innovation that develops this knowledge to create economic, social, and public value."

Research and development is another activity that involves science and technology. The OECD Frascati manual, which aims to create internationally comparable measurements and statistics, provides the following definition (OECD, 2015).

Research and experimental development

Research and experimental development (R&D) comprises the creative and systematic work undertaken in order to increase the stock of knowledge—including knowledge of humankind, culture, and society—and devise new applications of available knowledge (Ijichi, 2016a).

Changes in the quality of science, technology and innovation

This raises the question of how science, technology and innovation is changing. The following perspectives are considered to be important and indicative of change:

- Globalization: As science, technology and innovation is expected to contribute to resolving global social issues such as sustainability and social inclusion, global cooperation spanning multiple countries and regions is becoming increasingly necessary for science, technology and innovation activities.
- Multidisciplinarity and transdisciplinarity: Rather than a single research field, contributions from multiple research fields—that is, a multidisciplinary approach—are needed to respond to complex social issues. Moreover, the transdisciplinary efforts necessary to address real social issues require not only a diversity of science, but collaboration with diverse actors in policy and industry, as well as citizens. The background to this is a major shift in the segmentation of knowledge, elemental-reductive methods, and the mechanistic view of nature in science and technology that has supported modernization—features which have provided continuous support since the birth of science right through to the twentieth century (Tateo Arimoto, 2015).
- Digitalization and Digital Transformation: Dramatic developments in digital technology and AI are expanding the possibilities for using big data, changing the creation and sharing of knowledge and the structure of the economy and society (OECD, 2019). At the same time, the research environment, research methods, and the way in which research results are shared are also changing

(OECD, 2020). It has been suggested that this could lead to a shift in the nature of science from hypothesis-testing to data-driven science.

- Openness: Digitalization has provided significant opportunity, with research activities undergoing major changes as a result. For instance, the digitization of academic journals since the 1990s has led to the open access movement, and the tried and tested development of platforms and services to manage, hold, share, and publish research data and processes. This has prompted a reconsideration of research activities and the researcher ecosystem, including the significance of articles, journals, and peer review, as well as research assessments drawing on limited features such as the number of articles and citations (Kazuhiro Hayashi et al., 2019).
- Democratization/Diversification of Stakeholders: In addition to professional researchers working in institutionalized organizations, a variety of players (including citizens) are expected to participate in research and innovation activities through initiatives like citizen science, leading to the democratization of science, technology and innovation. This will be predicated on several factors, including: the public availability of research results through the opening up of scientific research and innovation activities spurred by digitization, the diversification of sources of research funding to include means such as crowdfunding, and the emergence of co-creation research projects based on the participation of citizens and other stakeholders in research activities and innovation activities (Hayashi Kazuhiro et al., 2019).

Changes in the science, technology and innovation policy framework, including its scope and objectives

Amid the aforementioned changes in science, technology and innovation, changes are taking place in policy formation frameworks, including the objectives, targets, and scope of science, technology and innovation policies. The following perspectives are considered important and reflect some signs of change:

- The theoretical framework (framing) of science, technology and innovation policy is changing. In a review of the relevant literature, Kobayashi Shinichi et al., (2019) trace these changes as follows. The first framework is “innovation for growth,” which is based on a linear model wherein innovation occurs when companies commercialize scientific inventions at universities and other institutions through applied research, leading to economic growth, and which emphasizes cross-sectoral interaction and feedback loops at each stage. The second framework is the “National Innovation System.” Today, the third framework is shifting toward “transformative change,” which involves the transformation of the entire socio-technical system and integrates socioeconomics and technology with a view to solving complex and wide-ranging social issues. This framework for science, technology and innovation policy corresponds to “mission-oriented innovation policy” and “grand challenges” and “global challenges” like the SDGs.
- This change in framework can be viewed as a shift toward impact-oriented STI policy. The scope and objectives of policy have expanded from science and technology policy—where the main target

of policy has been the results of science and technology—to science, technology, and innovation policy, which emphasizes impact and outcomes, including economic growth and innovation creation, as well as achieving wellbeing and resolving social issues.

- The value attached when setting policy goals is shifting from economic growth to the diverse happiness of individuals and society. Since the high-growth period, the importance of both quantitative growth (GDP growth) and qualitative growth such as well-being—including psychological aspects—has long been regarded as necessary. However, measuring social progress beyond GDP growth continues to present a challenge (Joseph E. Stiglitz et al., 2020). In science, technology and innovation policy, the role of science, technology and innovation in designing an inclusive society is increasingly being recognized alongside an emphasis on solving social problems. In the Sixth Science and Technology Basic Plan, a society in which "the diverse well-being of each individual" can be realized is positioned as an important component of the future society that could be called Society 5.0.
- Underlying these changes, the use of knowledge from the humanities and social sciences is becoming increasingly important in science, technology and innovation and related policy creation. The Sixth Science and Technology Basic Plan, which began in FY2021, calls for "the creation of diverse 'knowledge' that includes not just the natural sciences but also the humanities and social sciences, and the redesign of society as a whole through the use of 'integrated knowledge'."[13]
- The importance of scientific advice in policy creation is also becoming increasingly important (Tateo Arimoto et al., 2016). As society deals with the aftermath of disasters, such as the 2011 Fukushima Daiichi nuclear powerplant incident and the COVID-19 pandemic, which has raged since 2020, the nature of scientific advice and its challenges have become a matter of social debate. This gives rise to the need for society as a whole to acquire the ability to discuss and share scientific knowledge itself, which involves uncertainty, and the social implications of that knowledge.
- At the same time, positioned by governments under a more utilitarian framing, science has become a tool for national and international development (Gluckman, 2016). The use of knowledge and the speed of innovation present both challenges and opportunities for our societies and governments. Together with the balance between competition and cooperation, there is a continued recognition of the importance of science and technology diplomacy to this end.

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