Chapter 1 - I

Science, Technology, and Society on Data

: From the Perspective of Science and Technology Studies

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Modern society, represented by digital platforms, is an era in which various data are collected and used in many different situations. As discussed in the chapters of this book, these situations occur everywhere in our lives, including in health, education, and work. Consequently, benefits, such as personalized healthcare, education, and work, as well as various problems arise. This study examines the issues that have arisen regarding the collection and use of such data within the framework of the Science and Technology Studies (STS).

1 What is STS?

Science and technology have permeated every aspect of our daily lives and we cannot live without them. However, simultaneously, they can have negative impacts on society, such as environmental degradation (e.g., global warming) and various accidents. STS examines how scientific knowledge and technology are created and how they relate to society from the perspectives of the humanities and social sciences.

STS as a field of academic research has developed since the 1970s, and STS scholars have visited science and technology sites, such as laboratories, to analyze how scientific knowledge and technology are created through the interaction of people and articles, how the created scientific knowledge and technology affect society, and vice versa, how society affects scientific knowledge and technology [Felt et al.(eds.) 2016; Fujigaki (ed.) 2020; Hibino et al. (eds.) 2021; Matsumoto (ed.) 2021; Sismondo 2010; Tsukahara et al. (eds.) 2022].

This study examines the collection and use of data from an STS perspective, which involves data science and other science and technology experts, as well as the general public, who are non-experts. The following sections consider the issues that arise when experts or non-experts in science and technology interact with data.

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2 Data and Science and Technology

(1) Data-Centrism

As science and technology advance and enable to collect and process large amounts of data, data-centric science, such as data-intensive and data-driven science, has emerged as a "fourth paradigm" in contrast to existing sciences such as experimental/observational, theoretical, and computational fields [Kitamoto 2021]. With the rise of data-centric science, it is expected that data collected from various fields can be used to introduce innovative perspectives, accelerate research, and reduce costs [Edwards et al. 2011].

However, the expansion of data-centered science has had various effects on scientific disciplines. For example, biology has traditionally focused on the morphology of organisms. However, molecular biology, which studies organisms from the perspective of physics, was introduced. Organisms are now analyzed from four types of bases: adenine (A), thymine (T), guanine (G), and cytosine (C). DNA, the blueprint of an organism, is digital data recorded in a sequence of these four types of symbols [Taguchi 2020], and molecular biology aims to understand organisms by analyzing these data. With the birth of molecular biology, data-centrism was introduced into biology, and organisms were understood based on large amounts of digital data. Moreover, this expansion of data-centrism in science can be observed in other scientific fields, which offer some resistance.

Toxicology analyzes the response of organisms to toxins. It originally analyzed the response of organisms to toxins in terms of changes in their morphology. However, the field of toxicogenomics, which analyzes the responses of organisms to toxins based on the analysis of their base sequences, has emerged. Although, this new discipline has faced resistance from traditional toxicology, in response, toxicogenomics has expanded its influence by building databases that are accessible to many scholars and by bringing on board various fields of research outside of toxicology [Shostak 2005]. Similarly, there is friction between microbial ecology, which analyzes microorganisms based on their shape and behavior, and molecular microbiology, which analyzes microorganisms based on their nucleotide sequences; however, microbial ecology is overwhelmed by molecular microbiology in a data-centric approach [Sommerlund 2006].

(2) Data Integration

Although data-centrism is expanding and there is a backlash against it, the scope of science has broadened in recent years, more opportunities are available to collaborate on projects in multiple fields than in only one field. In addition, with the rise of data-intensive and data-driven science, it is expected that data from different scientific fields will be shared and leveraged. Amid this trend in interdisciplinary research, there has been a move to build cross-disciplinary databases that integrate data from each scientific field; however, several problems have arisen in this area. First, different scientific fields have different ideas about the definition of data, the purpose of data collection, and how data are collected, hindering creation of a database that is universally agreed upon and usable [Leonelli 2012; Star and Ruhleder 1996].

Issues related to metadata have also been raised in the context of data integration. Metadata refers to "data about data" [Hey and Trefethen 2003] and "information about data" [Michener 2006], including an overview of the data and where and when the data were created [Edwards et al. 2011]. Metadata ensures the reliability, sharing, and effective use of data [Bowker 2005; Mayernik 2019]. Moreover, it is necessary to create a common infrastructure for metadata in interdisciplinary research. However, as scientific disciplines and scientists differ in their consideration and value of metadata, conflicts arise between them in creating standardized criteria for metadata, and considerable time and effort is required to coordinate these conflicts. Moreover, even when common standards for metadata are established, they may not be applicable in interdisciplinary research [Edwards et al. 2011]. As data-centrism increases in science, interdisciplinary data sharing is expected to advance scientific research and improve efficiency. However, there is an optimistic aspect of these expectations.

(3) Science, Technology, and Culture

Data-integration problems are related to the existence of different cultures in different scientific fields. Knorr-Cetina compared molecular biology and high-energy physics [Knorr-Cetina 1999].

In her study, she clarified that in molecular biology, scientists directly handle the experimental objects and treat the target organisms as if they were machines. In contrast, in high-energy physics, large experimental equipment is operated by a large group of scholars, and the analysis of indirectly graspable objects is conducted while the experimental equipment is treated as an organism. In addition, she highlighted differences in research objects, methods, and scholar behavior between the two scientific fields. For example, in molecular biology, individual contributions are valued and their names are clearly stated in publications, whereas in high-energy physics, collaboration is valued, and individuals are buried among many co-authors in publications [Knorr-Cetina 1999; Suzuki 2022].

Knorr-Cetina attributed these differences between molecular biology and high-energy physics to the differences in epistemic cultures between the two [Knorr-Cetina 1999]. As people in different societies have different cultures, different fields of science have different cultures; therefore, there are differences in data interpretation, collection methods, and so on, which complicate data integration.

Furthermore, it is often assumed that science and technology are researched and developed in the same manner worldwide, and that the results are used in the same manner. However, in reality, the state of scientific research and technological development differs according to the policies of each country and the expectations of its people. Moreover, differences exist between countries and regions in the acceptance and use of scientific knowledge and technology [Hibino et al. (eds.) 2021]. Studies focusing on these differences in the state of science and technology in different places are called Geography of Science [Livingstone 2003].

Regarding databases, many cases exist in which international integration is expected, not simply between scientific disciplines. However, issues have arisen in terms of international database integration from the perspective of Geography of Science. In particular, for human-related databases, each country has its own laws regarding the collection, registration, and use of data. Accordingly, databases are constructed and operated differently in each country based on these laws. Therefore, when integrating databases internationally, it is necessary to harmonize the relevant laws of each country. However, integrating laws that are closely related to the culture and social context of each region internationally presents a significant challenge, and the integration of international databases requires considerable effort [Suzuki 2017].

As described above, various impacts and issues surrounding data are clear, such as the impact on other scientific fields as the influence of data-focused science expands and the challenges that arise in collaboration with other scientific fields and in sharing data. However, not only experts are involved with the data. Therefore, this study considers the issues that arise in relation to non-experts with respect to data.

3 Data and Citizens

(1) Citizen Science

Scientific activities have been conducted by experts; however, recently, the general public (citizens), who are not science experts, has begun to participate in scientific research. Such activities are referred to as citizen science, which is defined as "citizen-participatory projects carried out in collaboration between researchers and other experts and citizens" [Ikkatai 2020] or "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions" [Hayashi 2015; Oxford English Dictionary 2014]. Citizen science involves a wide range of objectives and methods of participation [Hara et al. 2020; Ikkatai 2020]. These include activities such as groups of AIDS patients conducting their own research and contributing to the development of new clinical trial methods [Epstein 1996], as well as Do It Yourself Biology, which uses open-source data to create biotechnological innovations in a home garage or elsewhere [Hibino et al. (eds.) 2021; Mirowski 2018; Wohlsen 2011].

Moreover, the citizen science movement is associated with data. Recently, new ways of conducting citizen science have emerged through the use of digital platforms. The public currently participates in online scientific research in the form of data collection and analyses. For example, the Galaxy Zoo project, launched at the University of Oxford in 2007, allows online citizen participants to analyze and classify images of galaxies based on their shape. In 2009, Galaxy Zoo was integrated into a scientific research platform called Zooniverse. Here, various research projects in the natural sciences and humanities remain open to the public, and citizens volunteer to participate in each project and analyze data online. In a citizen project called Foldit developed by researchers at the University of Washington, citizens can predict how protein molecules arise from DNA through a computer game. The eBird citizen project, run by the Cornell Lab of Ornithology, allows citizens to upload the information they observe about the birds to an online site and contribute to the creation of a global bird distribution map [Nielsen 2011].

Various digital platforms for citizen participation in scientific research have been established, and various mechanisms have been created to encourage continuous participation. The expansion of such platforms for scientific research can create a change in the relationship between scientists and citizens in a manner that the privileged status of scientists is removed, and both scientists and citizens become users of the platforms [Baudry et al. 2022; Nielsen 2011].

(2) Democratization

One area in which citizens are expected to collect and use data is healthcare [cf. Ministry of Health, Labour and Welfare, Advisory Panel for the Promotion of AI Utilization in the Healthcare Sector 2017]. The use of data collected from patients will enable doctors to provide medical care remotely, and enable personalized medical care. Although data-driven healthcare is expected to improve patient health, challenges have also been identified.

For example, wearable devices and online symptom checkers allow patients to generate their own health data with a focus on collecting and integrating these data. The European Union (EU) has invested heavily in the creation of the European Health Data Space (EHDS) to integrate data from patients' wearable devices with other health data. These investments aim to help individuals manage their health data, improve healthcare accessibility and effectiveness, and enhance the quality of life. Further, it will enable healthcare professionals to perform their jobs more effectively by providing easy access to patients' health data [Dorazil 2020; European Commission 2022a; 2022b]. However, these expectations are optimistic. In Denmark, it is considered a citizen right for patients to share their information with the healthcare system, and the digitalization of healthcare is underway, aiming to integrate various health data, including data from patients' wearable devices [Finansministeriet 2022; Langstrup 2019]. However, interviews with general practitioners (GPs) who treat patients [Haase et al. 2023] revealed that patients rarely bring their health data based on wearable devices and online symptom checkers. Further, GPs do not consider such health data as objective test values, but as subjective, comparable to patient narratives. They are not adequately prepared to integrate and use patient-generated data in clinical practice, and considerable effort is required to interpret and explain how the data shared by the patient relate to the disease. This has resulted in a situation where the data are disregarded or poorly used by both patients and doctors, limiting its effective use. The use of health data generated by individual patients, including wearable devices, is expected to democratize and streamline healthcare. However, the reality is the opposite; neither patients nor doctors effectively use health data, and the situation is increasing the burden on both parties [Haase et al. 2023].

(3) Privacy

In addition, privacy issues have been raised regarding the data collected and used. Technologies such as smart home appliances and social robots that collect various data from users, operate home appliances, search for information, and communicate with users based on such data, make people's lives more convenient. However, Google, for example, has been criticized since it was revealed that Google patented a toy that collects data on the various words and actions of its users and responds to them [BBC 2015; Kukita et al. 2017]. One concern is that the shape of the toy allows children to play with it and unknowingly violates their privacy. However, it has also been revealed that Amazon's smart speakers for children collect and record users' voices indefinitely [BBC 2019; 2023] and that outsiders were listening to users' voices in relation to a voice assistant provided by Apple [The Guardian 2019]. Privacy issues associated with data collection and use are highly controversial. Some users are more vulnerable than others, such as children and the elderly, and the risk of their privacy being easily violated or manipulated is problematic [Coeckelbergh 2020].

(4) Relationships/Discrimination

Living in a world based on massive amounts of data, and the emergence of digital platforms have had a profound impact on how we relate to one another. Turkle argued that while digital society has enabled people to connect with people worldwide online, it has also resulted in a loss of opportunities for physical interaction, which may result in a loss of the ability to know oneself, care for others, and empathize [Turkle 2011; 2015]. A study conducted at the University of Michigan determined that today's students are less empathetic toward others than they were 20–30 years ago, and the existence of casual relationships through social media and other means that do not involve in-person contact has been cited as a contributing factor [Kukita et al. 2017].

The issue of discrimination caused or encouraged by data-related technologies has also been raised. Facial recognition technologies offered by various companies have been found to be more accurate for lighter-skinned men and less accurate for darker-skinned women [Najibi 2020]. This means that darker-skinned people are more likely to be misidentified than lighter-skinned people, and that women are more likely to be misidentified than men. In 2020, a facial recognition system misjudgment led to the wrongful arrest of a man of African descent [CNN 2020]. Furthermore, technologies that identify lesions based on patient data often perform poorly on patients from other populations because the majority of patient data emerges from a specific population, resulting in unfair diagnostic bias [Japan Medical Association Advisory Panel on Bioethics 2022]. The presence of bias in these data-based techniques and decisions has been observed in various settings [cf. Yamamoto and Ozaki 2018]. However, the underlying cause is the potential bias in the human population that creates the algorithms used to collect and analyze data, as well as in society at large [Coeckelbergh 2020; Ema 2021]. It has been suggested that the values of privileged and educated young white males among algorithm creators may drive this discrimination [Coeckelbergh 2020; Hu 2015].

Discrimination within the field of scientific and technological research and development is also an issue. For example, in the United States and Europe, visas are issued to highly skilled foreign software engineers who are hired by companies as casual workers. These casual workers are often from Asia, and the analysis reveals that this is owing to the prejudices that Asian programmers have high mathematical thinking skills, prefer rote jobs, come from overcrowded areas where competition is intense, and are naturally hardworking, making them more suited to tedious and grueling work [Amrute 2020].

4 Living in a Data Society

It is believed that modern society, based on the collection and use of large amounts of data, will provide the goods and services that individuals desire, and will also allow non-experts to participate in knowledge and technology that used to belong to experts, thereby democratizing science and technology. However, various challenges have been identified in this data society and it has become clear that the envisioned future is not necessarily rosy. In addition to the issues aforementioned, several other issues are expected to arise in the future, such as platform security and liability when problems arise, the digital divide between those who have access to the platform and those who do not, platform transparency, and the relationship between the current system and the platform.

The first important aspect of such a light-dark data society is the dispassionate perspective on science and technology. People often imagine science and technology to be certain, rigorous, and trustworthy [Fujigaki 2005; Renn 1995]. However, as discussed in this paper, science and technology face various challenges and limitations. Although science and technology have the potential to make our lives richer, they are not a panacea; they pose various challenges and can sometimes be detrimental to society. It is important not to have blind faith in science and technology but to accept a middle path, without denying it altogether.

To solve various problems related to science and technology, it is necessary for different people in society to discuss the state of science and technology and the society that they produce together. Nuclear physicist Weinberg defined “trans-scientific questions” as questions that transcend science and cannot be answered by science alone as science grows in size and influence on society [Weinberg 1972]. Some of the data-related issues discussed in this paper involve aspects of trans-scientific questions.

In the past, problems related to science and technology were solved by scientists and engineers who were experts in these fields. However, it is no longer possible for scientists and engineers alone to solve problems that arose at the interface between science and technology and society, such as trans-scientific questions. Therefore, a participatory social decision-making method called Participatory Technology Assessment was implemented. Participatory Technology Assessment is a method in which ordinary people, who have been excluded from discussions on issues related to science and technology, analyze and evaluate the impact of science and technology on society and the problems it causes through dialogue with experts, and then propose solutions to these problems [cf. Hirono et al. (eds.) 2023]. Rather than restricting issues related to science and technology to a select few, we must discuss problems and solutions with many people.

Recently, much emphasis has been placed on examining the impact of advanced science and technology on society; in particular, the types of ethical, legal, and social implications/issues (ELSI) that are likely to arise from new science and technology. ELSI was first proposed in the context of the Human Genome Project, which was launched in 1990, and has since been applied not only to biotechnology, but also to various other scientific technologies, such as nanotechnology and artificial intelligence [Hirono et al. (eds.) 2023]. In addition, ELSI has evolved into Responsible Research and Innovation (RRI), particularly in Europe. RRI is characterized by its focus on the economy, in addition to the ethical, legal, and social implications/issues of science and technology. Scientists and engineers collaborate with citizens, policymakers, industry, scholars in the humanities and social sciences, and other third sectors such as NGOs to improve science and technology and society by considering issues related to science and technology and their solutions from the early stages of research and development of new science and technology [Fujigaki 2018; Kamisato 2022; Center for Research and Development Strategy, Japan Science and Technology Agency 2021]. Moreover, RRI emphasizes fairness in fields where science and technology are produced, such as eliminating discrimination in science and technology research and development [Fujigaki 2018; Center for Research and Development Strategy, Japan Science and Technology Agency 2021].

ELSI and RRI are sometimes considered as brakes that could lead to stricter regulation of science and technology and hinder its development. However, if scientists and engineers actively address issues related to science and technology and cooperate with various stakeholders, they will win public trust, which will lead to progress in research and development. Thus, the ELSI and RRI play the role of handles that lead science and technology to better development [Center for Research and Development Strategy, Japan Science and Technology Agency 2021].

The various data-related issues discussed in this study also need to be considered from the ELSI and RRI perspectives. It is expected that new science and technology related to data will continue to emerge and be introduced into society; however, it will be necessary to solve problems in collaboration with a wide range of stakeholders. Science and technology can potentially create new societies. We who live in a data society must be aware of this and take action to make such a society even better.

Acknowledgments

This research was supported by JST Moonshot R&D Grant Number JPMJMS2021.

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