Chapter 4
Modern Societies and Establishment of Scholarship

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Abstract The previous chapter discussed characteristics of contemporary societies in problems related to safety. Histories of birth of societies and cities and their maturing are deeply related to histories of birth and development of scholarship and science. This chapter overviews how scholarship and science were born, how they branched out and specialized, and then how they unified and formed interdisciplinary studies beyond boundaries of specialized fields. It also explains histories of various academic fields related to societal safety sciences.

Keywords Industrial revolution · Safety engineering · Scholarship · Scientific revolution

4.1 Human Societies and the Start of Scholarship

4.1.1 Origin of Scholarship

Oxford Advanced Learner's Dictionary defines the scholarship to mean "the serious study of an academic subject and the knowledge and methods involved." Subjects that we study at universities, philosophy, psychology, law, economics, sociology, science, engineering, and medicine are all scholarships systematized based on knowledge and theories. Here we will first review the origin of scholarships.

Human, since ancient times before civilization, empirically found regularities in the nature deeply related to their lives, i.e., movements of the sun and stars, transition of seasons, and change of weather. We then acquired knowledge about these natural phenomena and applied them to farming of crops and livestock. The ancient Mesopotamian civilization, said to had started around 3500 BC, had a number of city states. Priests and leaders that ruled the city states defined letters, numbering

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systems, weights and other measures, the calendar, and so on and acquired various knowledge about mathematics and astronomy. The ancient Egyptian civilization, said to had started around 3000 BC, carried the knowledge from Mesopotamia and established the basics of mathematics and astronomy.

During the time of Mesopotamian and Egyptian civilizations, people built canals and irrigation facilities for improving their farming work, and also huge structures like pyramids as city states formed. These works added knowledge about land survey and astronomy lifting people's understanding of the nature to much higher levels. People at the time, however, believed gods made nature's moves that gave people benefits and, however, at times would pose threats to the people. In other words, people were dominated by the nature leaving their destinies in the gods' hands. The understanding of nature at this time was merely an accumulation of empirical knowledge that was necessary for autocracy that led people's livings. Thus, there probably was no attempt to explain nature systematically in a scholarship manner.

When poleis were established in ancient Greece around 800 BC, efforts to establish a systematic explanation of the accumulated empirical knowledge about the nature with unified principles started. This move is understood as the origin of scholarship that attempted to explain the world by systematically understanding the nature with laws and theories within a civilization that explained all phenomena as god's act.

Thales (~625 BC–~547 BC) is said to be the first philosopher that put scholarship into practice. Thales and other natural scholars of Ionia searched for "arche (principle)" that formed the origin of nature and all things. Thales believed water was the arche constructing everything in the world and preached that everything was a transformation of water. Ancient Greek philosophy started by Thales was carried over to Plato's (427 BC – 347 BC) idealism (theory of "ideas"), and the basis of scholarship was established. Idealism asserts that reality is constructed upon idea and individual reality that we sense is merely provisional images. Plato attempted to understand the world of reality in a top-down manner and theoretically systematized it with ideas.

The concepts of natural scholars starting from Thales were summarized by Plato's student Aristotle (384 BC – 322 BC). Aristotle was critical against the concept of placing formless ideas in the center and started to preach the concepts of "eidos (form)" and "hulê (matter)." Eidos are existing substances that are observable in the real world and hulê material or ingredients that form substances. For example, for a wooden table, its eidos is the shape of the table and hulê is wood. Describing substances under observation with distinction between eidos and hulê is the basics of scientific observation. Aristotle built the basic scientific theory and methodology of describing the results of observing substances, storing the results, organizing and systematizing them. He further divided scholarship into specialized fields depending on the substance. These fields were physics, astronomy, meteorology, politics, ethics, and so on, and Aristotle systematized each field. Understanding nature in this manner largely contributed to raising people's interest into scholarship. And categorizing the nature, setting the divided nature substances as objects for fields, and understanding the world in a bottom-up manner are the first of scientific thinking, and his work is said to be the origin of the variety of scholarships.

4.1.2 *Decline of Scholarship in the West and Its Development in the Arabic Regions*

The number of scholarships originating from Aristotle of ancient Greek continued to develop into the first century AD. Then, however, scholarship in Europe declined until the Middle Ages. Techniques in civil engineering and practical solutions for supplying water and building roads advanced; however, scholarships as science did not record much progresses.

Among the causes of the decline of scholarships in European societies during this period, one was that development of physics in Greek came from the desire to "understand the structure of the world." Europe back then was dominated by the Christian churches which taught that God was the only being that clarified the truth. Scientific scholarships that tried to explain various phenomena based on theories conflicted with Christian theology, thus, were frowned upon and declined.

Modern European historians look back at the time after ancient Greek to the Middle Ages as the "dark ages" of the world's scientific development. Recent researches, however, revealed that Islamic civilization advanced in Arabic countries during the ninth to the fifteenth centuries (Jacquart 2005). During the era in Arabia, references by Hippocrates (460 BC–375 BC), Plato, Aristotle, and so on were translated into Arabic leading to development of Arabic science in astrology, mathematics, and medicine. During the time of Abbasid Caliphate (750–1258), an intellectual center "House of Wisdom (Bayt al-Ḥikma)" built in the capitol Baghdad gathered scholars of all fields and all ethnic groups of Turkish, Iranian, and Jewish. It is not an exaggeration to say that Arabic science was ahead of European science from the eighth to the eleventh century (Haskins 1927). The Arabs took over the Christianity-dominated Europeans to lead the world of scholarships.

4.1.3 *Birth of Universities and the Twelfth-Century Renaissance*

In the twelfth century in Europe, movements started to reevaluate the heritages of ancient Greek civilization and revive them. The ancient Greek scholarships not passed on within Europe were transferred to Arabia to go under further development and were reimported back to Europe and translated from Arabic to Latin. The restoration of scholarships in Europe then that started by accepting Arabic sciences is called the twenty-first-century Renaissance (Haskins 1927).

Table 4.1 Primary universities and their years established

Year established	Name (Country)
1088	Università di Bologna (Italy)
1150	Université de Paris (France)
1167	University of Oxford (England)
1173	Università degli Studi di Salerno (Italy)
1204	Università a Vicenza (Italy)
1208	Universitat de València (Spain)
1209	University of Cambridge (England)
1215	Università di Arezzo (Italy)
1220	Université d'Orléans (France)
1222	Università degli Studi di Padova (Italy)

Data source: Haskins (1923) and latest data

During that time, a number of universities were born in the cities of Europe (Table 4.1) where translations of Arabic science into Latin took place. Universities at that time had the task of studying the vast amount of knowledge from the ancient Greek sciences and spread them throughout Europe (Haskins 1927). During this time, books on medicine by Hippocrates and publications by Aristotle were translated into Latin to merge into systematic teachings with those of Christianity. Philosophy based on Aristotle's work was called "scholastic philosophy" and turned into major scholarships at universities in Europe. The rise of Greek scientific rationality, however, led to heated discussions with Christian beliefs. Aristotle's descriptions of the world conflicted with the teachings of Christianity and European scholars argued over where the truths were (Haskins 1927).

After the twelfth century was over, the Faculty of Arts at the University of Paris took the central role in promoting "Latin Averroism" that supported teachings by the Arabic philosopher Averroes (Haskins 1927). Averroism taught a double-truth theory that despite the discrepancies, both Aristotle's philosophical truth and truth of the Christian teaching were both acceptable. The churches and orthodox theologians strongly opposed Averroism and often condemned it heretical. In 1277, the bishop of Paris, Étienne Tempier (? – 1279), researched the debates at the University of Paris and declared that anyone in support of the 219 Averroism propositions will be condemned and kicked out. In Europe, where visions of the world that casted doubt on Christianity were unacceptable and while accepting Aristotelianism, its cosmology and theory of motion were not accepted.

4.2 Birth of Modern Science

4.2.1 Pioneers of Modern Science

In the European societies back then, people believed in Ptolemaic geocentric cosmology that placed the earth at the center of the universe. Nicolaus Copernicus

(1473–1543) discovered that his theory that set the sun at the center of the universe explained planetary motions rationally and beautifully. This Copernican theory was often quoted in scientific discoveries that conflicted with the Christian belief. Copernicus, however, had a Christian church title and is said not to have explained Copernican theory in a way that opposed Christian teachings (Butterfield 1957).

Astronomer Tycho Brahe (1546–1601) kept accurate records of celestial observations. Johannes Kepler (1571–1630) discovered that planets circled around the sun in elliptical orbits with the sun being one of the foci and that the line segment connecting a planet and the sun swept regions with constant areas during a set time period. In his publication *Astronomia nova* (New Astronomy), he wrote about what are known today as Kepler's first and second laws of planetary motion. At about the same time, Galileo Galilei (1564–1642) discovered the "law of falling bodies" that the time for a body to fall freely was independent of its mass and was proportional to the square of the elapsed time.

In the seventeenth century, scientific approaches to the huge amount of data, collected through celestial observations and physical experiments, started to look for essential relations in natural phenomena trying to construct unified theories and axioms. René Descartes (1596–1650) discovered the law of inertia that a body in motion continued to move, unless there was resistance, without applying force to it and opened the world of objective mechanical theories governed by mechanical forces. Kepler, Galilei, and Descartes are said to be the scientists that built the basics of modern science.

Both Kepler and Galilei, however, believed that God was a great mathematician and the nature God created was written in mathematical words. Their pursuit of nature was in line with their beliefs in Christianity, and they were trying to understand God's will. Science today has a variety of aspects including human ruling of parts of nature, experiments, discovery of laws, mathematical physics, and mechanical views of the world. Each of these elements had profound relationships with Christian beliefs in Europe when it was born at the dawn of modern science (Haskins 1927).

Isaac Newton (1642–1727) from England gathered the results of Copernicus's "Copernican theory," Kepler's "laws of planetary motions," and Descartes's "law of inertia" and synthesized them into a theoretical system to form the basics of modern science. Newton, in his 1687 publication of *Philosophiæ Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy), mathematically proved planetary motions and explained the "law of universal gravitation," "law of inertia," and other results. His work proved that bodies and celestial motions are mathematically explained in a unified framework. By the end of the seventeenth century, a highly generic system of theories was established instead of a collection of fragments of knowledge. An English historian Herbert Butterfield calls this era of revolutionary changes in natural science that gave birth to modern science, "the seventeenth century scientific revolution (Butterfield 1957)."

4.2.2 Birth of Academic Societies and Specialized Fields

Among the contributors to modern sciences, some had teaching jobs at universities. Galilei taught mathematics and astronomy at University of Pisa and University of Padova. Newton held the position of Lucasian Professor of Mathematics at the University of Cambridge. In the seventeenth century, the scientists established new communities, academic societies outside of universities. The wealthy class in control of politics, economy, and culture in cities competed with churches at the time and sponsored their formation and operations. "Accademia dei Lincei (Academy of the Lynx-Eyed)" founded in 1603 in Rome for the pursuit of nature is said to be one of the oldest of such societies (Furukawa 2000). In Firenze (Florence), Italy, the House of Medici sponsored the "Accademia del Cimento (Academy of Experiment)," and many scholars conducted a variety of experiments as the academy name suggests. In 1662, the King of England, Scotland, and Ireland, Charles II (1630–1685), gave Royal Charter to the Royal Society of London, started in 1660, that functioned as the hub for scholars dedicated to new scholarships for studying the nature. In 1665, the society started periodic publication of *Philosophical Transactions* so the members could publish their research results. It was the beginning of the system of academic journals for scholars to publish their accomplishments in scientific researches.

The establishment of Royal Society of London was largely affected by Francis Bacon's (1561–1626) scientific ideology that science ruled the nature. Bacon, known for his quote "For also knowledge itself is power," believed that nature given to human by God could also be ruled with the power of knowledge. The Royal Society of London was established as a community for researchers of the nature that strived to understand many natural phenomena through observations and experiments. In 1666, "Académie des sciences (Academy of Sciences)" was established in Paris which was nationally supported, instead of by churches or private patrons, to carry out scientific researches under the support by the nation (Ornstein 1928).

The spirit of modern sciences established by Bacon, Descartes, Newton, and so on inspired French philosophers in the eighteenth century, and they believed the scientific revolution would not only advance natural research topics, but it would also affect the entire human activities (Butterfield 1957). Illuminati at the time tried to change Christian recognition of nature and social recognition by the general public with modern sciences based on rationality.

In the nineteenth century, natural sciences advanced internally at an enormous speed. Physics, chemistry, biology, and geology especially shaped up their own independent scholarship fields (Butterfield 1957). In France, in fact, a number of independent academies started their activities: Académie Nationale de Pharmacie (French National Academy of Pharmacy) in 1803, Société de Géographie (Geographical Society) and Société d'Histoire Naturelle de Paris (Paris Natural History Society) in 1821, Société géologique de France (France Society of Geology) in 1830, and in 1843, Société de Chirurgie de Paris (Society of Surgery). They were the start of specialized associations formed by scientists in the study area where they could cooperate in pursuing studies in the applicable fields, a style still carried on today. In Germany and France, modern universities for advanced education were also established. In the twentieth century, many academic fields taught today at universities founded the basics of their scholarship systems, and today, universities that carry out researches and education in each field exist over the world outside of Europe as well.

4.3 Advancement of Scholarship and Specialization

In general, scholarships are categorized into “natural sciences,” “social sciences,” and “humanities” (Table 4.2). Natural sciences encompass a group of scholarships that study laws of natural phenomena. Categorization in Japan often takes the form of “rikei (scientific)” and “bunkei (social sciences and humanities).” Scholarships in rikei correspond to natural sciences and those of bunkei to social sciences and humanities. Social sciences study phenomena in human societies and humanities study culture that human has created.

The idea of categorizing scholarships into natural sciences, social sciences, and humanities is relatively new. Natural phenomena like motions of the sun and stars, flow of water in rivers attracted the interest of scientists in old days. Scholarships started from pursuing truth in rules and matters that surrounded people, and in ancient Greece, it was called “philosophy.” How the human hearts worked and the language that people used also caught the attention of scholars as time passed by. It was natural that we also started looking at monetary economy, law, and administration as study subjects with the development of human societies.

During the dawn of scholarship, each scholar took interest in a variety of subjects and pursued the truth. As knowledge accumulated and scholarship made progress, the scholars turned their interest into more profound realities. The subjects that each scholar studied gradually narrowed down into specific areas, and scholarships headed into diversified specific areas. Table 4.2 shows the general scholarship areas. Engineering today are further divided into, mechanical engineering, civil engineering, electrical engineering, chemical engineering, and so on. Further, the scholarship of mechanical engineering is split into a number of specialized areas of fluid dynamics, thermodynamics, strength of materials, and so on. Fluid dynamics alone can also go under finer divisions. Scholarships today have gone through

Table 4.2 Categorization of scholarships

Scientific category	Primary scholarship fields
Natural sciences	Physics, chemistry, biology, astronomy, medicine, engineering, …
Social sciences	Economics, operation research, law, sociology, administration, education, …
Humanities	Psychology, history, linguistics, religion, literature, philosophy, …

division after division with the advancement of what to study and research, and the trend will probably continue that way in the future.

As scholarship advanced, "specialists" that study specific areas in detail increased. A single specialized area, however, can only apply principles and law to a narrow range, and specialists have hard time applying their skills or creating new concepts. This led to new ways that are catching the attention of training human resources that have one detail specialty but also basic knowledge over a wide area. Tom Kelley and Jonathan Littman call this type of person "T-shaped" to distinguish them from "I-shaped" people that thoroughly study single areas (Kelley and Littman 2000). Those with wide basic knowledge over a wide area with two or more specialized subjects are called "Π(Pi)-shaped" people. Here, "I," "T," and "Π" are not the first characters of English words, but they are selected for their shapes representing the concepts. You can understand that the length of the horizontal bars represents the wide knowledge and vertical bars the number of specialties.

Whether "T-shaped" or "Π-shaped," the width of the basic knowledge was thought to stay within a certain range. Leaders of corporations, local or central governments, however, have to understand to a certain extent of all areas, e.g., economics, law, and physics, to give directions when needed. Solutions for detailed problems can be left to specialists in the areas; thus, the knowledge in each scholarship area does not have to reach so deep. Leaders are required to have knowledge over a wide area in the real sense that is not framed within the system of scholarships in Table 4.2, that is, the qualification for a "generalist." The advancement of scholarship led to specialization in each specific scholarship area; however, the society today needs generalists having knowledge over a wide range of specific areas and being able to give proper directions to real specialists in each area.

4.4 Births of Safety Engineering, Disaster Science, and Risk Analysis

This section overviews how specific fields related to societal safety sciences, i.e., safety engineering, disaster science, risk analysis, and so on were born. As we explained in Sect. 4.2.2, the medieval Europe saw huge advancements in science called "scientific revolution." In England, "industrial revolution" started to take shape in the mid-eighteenth century. The industrial revolution gave leaping steps forward for scientific technologies and, however, also caused accidents at levels never expected before. James Watt's (1736–1819) steam engine is often quoted as a symbol of industrial revolution. The steam engine is a machine that converts thermal energy of steam into mechanical power. The steam engine allowed machines to produce huge forces and transfer ships and railway cars at high speed. The strong machine and fast-moving transporters caused disastrous accidents when human body contacted them in wrong ways. As the number of accidents rose, people turned conscious about safety and the concept of industrial safety was born. Then it was followed by the scholarship of safety engineering that sought ways of preventing accidents and disasters. Not only to design and produce safe machines, researches on the psychology of safety and laws to keep the societies safe are developed as well.

Human already knew about dangerous natural phenomena of earthquakes, typhoons, flooding, and lightning and planned to protect safety of their way of living before social disasters entered their lives with the advancement of scientific technologies. Back then, however, without the knowledge of how natural phenomena took place, human had to protect themselves with empirical methods. In fact, plate tectonic theory was developed only in the late 1960s. Observation balloons went up in the sky in the 1930s; however, we had to wait till 1960 to hear about weather satellites. Thus, it took "disaster science" a long time to make its way into the system of scholarships. Engineering technologies and social scientific studies can now protect human lives and societies to a certain extent.

Risk analysis is also a relatively new field of study. Today's societies with highly advanced scientific technologies started to see complex phenomena involving health, environment, ecosystem, economics, and all other fields beyond whether matters were dangerous or safe. As the concept of risk with uncertainty is ever more important, the "Society for Risk Analysis" was established in the USA. The societies today are subject to a variety of risks, and it is called "Risk Society" (Beck 1986). When we recognize events of traffic accidents, NPP accidents, natural disasters of typhoons and earthquakes, safety of food, and financial crises from the viewpoint of risk, our societies must now deal with them in an intelligent manner.

The advancement of scientific technologies made our lives rich; however on the other hand, we are faced with a variety of risks and safety concerns of large-scale disasters, concerns about resources, energy, and the environment that come with corporate activities, traffic accidents, and terrorism attacks. For us to build safe and secure societies is one of the most important problems to solve, and for that goal, we need to pursue research, take practical actions, and educate human resources. Problems with safety and security, however, are often hard to solve with a single force in a traditional field of specialized area. In search of solutions for safety and security issues of today's society, we have to build a new area of scholarship that gathers wisdom from a number of specialties.

Today, scientific technologies are deeply related to our society, but some scientific problems cannot be solved within the realm of science alone. We can pose questions to science in such situations; however, science alone cannot provide answers to them. The state is generally called a trans-scientific situation (Weinberg 1974). Issues related to safety and security often are trans-scientific. Solving a trans-scientific problem involves not just scientists, but citizens, as a stakeholder, have to take part in making decisions. Problems with safety and security directly relate to life and property; thus, we cannot leave them to decisions by others, and we cannot stay indifferent. We have to face the need to educate human resources with good knowledge in societal safety issues to solve the variety of safety and security problems in today's societies.

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