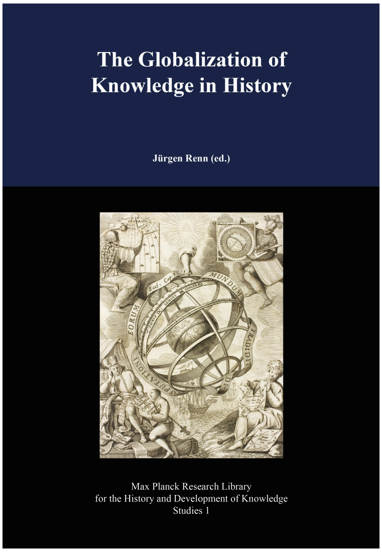
Max Planck Research Library for the History and Development of Knowledge
Studies 1

Matthias Schemmel:

The Transmission of Scientific Knowledge from Europe to China in the Early Modern Period



In: Jürgen Renn (ed.): *The Globalization of Knowledge in History*
Online version at http://edition-open-access.de/studies/1/

ISBN 9783844222388
First published 2012 by Edition Open Access, Max Planck Institute for the History of Science under

Printed and distributed by:
Neopubli GmbH, Berlin
http://www.epubli.de/shop/buch/17018

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de

Chapter 11
The Transmission of Scientific Knowledge from Europe to China in the Early Modern Period

Matthias Schemmel

11.1 The Global Spread of Modern Science

At the beginning of the twenty-first century, modern science is clearly global. It originated in early modern Europe and spread from there all over the world, either through the migration of people who brought it with their culture, as is the case for America and Australia, or through its adoption by non-European cultures, as is the case for China and Japan.[1] It is true that even today not all countries have the same means to produce scientific knowledge or to participate in global scientific communication. It is also true that national science politics and the decisions of local communities have an impact on the subject-matter of scientific research. But on a global scale there are shared bodies of scientific knowledge, shared scientific practices and shared criteria for the evaluation of scientific results, so that one may speak of a global culture of science. In particular, science is not expected to depend on the characteristics of one particular modern culture, such as the native language or the religious beliefs of those doing science.

It is this aspect of the universality of modern science, its compatibility with a wide variety of cultural backgrounds, together with the idea that science produces true statements about the world and the obvious usefulness of science for developing advanced technology, that may lead to the belief that the spread of modern science to non-European cultures was a matter of course, a simple process of adoption, possibly evolving at epidemic speed: cultures once infected by modern science and its merits could not but adopt it.

The example of China shows that this is not the case. In the seventeenth and early eighteenth centuries, just at the time when the early modern Scientific Revolution was taking place in Europe, the worldwide missionary efforts of the Jesuits brought Chinese society into direct contact with European science. Yet, modern science did not take root in China and in the first half of the eighteenth century, the transmission of European scientific knowledge to China came to a virtual halt. It gained new impetus only in the second half of the nineteenth

[1] To say that modern science originated in early modern Europe should not be taken as a denial of its non-European roots. For the multi-millennial history of knowledge transmission throughout Eurasia and northern Africa, see survey chapter 9.

century when the arrival of protestant missionaries led to a second wave of science transmission under drastically changed political conditions. But it was not before decades of intellectual, social and political struggle for its reorganization that the Chinese knowledge system attained a new stable structure that incorporated modern science.

This chapter will discuss the first wave of transmission of European scientific knowledge to China in the seventeenth and early eighteenth centuries.[2] After a very brief overview of science and technology in China prior to the arrival of the Jesuits (section 11.2), the chapter discusses how the Jesuit enterprise in China brought about the transfer of European scientific knowledge (section 11.3). The religious and political contexts that made this knowledge transfer possible imposed at the same time severe constraints on it (section 11.4). The result was a selective integration of European knowledge into the Chinese knowledge system, without, however, profoundly changing, let alone revolutionizing it (section 11.5), while the structure and content of the transferred knowledge was transformed in a process of assimilation to the Chinese knowledge traditions and institutions (section 11.6). The chapter concludes with a summary interpretation of the transmission of scientific knowledge from Europe to China in the early modern period in terms of the encounter of two separate systems of knowledge (section 11.7).

11.2 Science and Technology in China Before the Jesuit Intervention

To understand the Chinese reception of European science, it is crucial to take into account the existence of Chinese indigenous science. The term 'indigenous' should not suggest that Chinese science before the Jesuit intervention had developed in isolation. Just like early modern European science, it was the result of a multi-millennial history of knowledge transmission throughout the Eurasian and (northern) African continents.[3] But direct intellectual exchange between the western and the eastern extremes of the Eurasian continent was scarce, so that the arrival of the Jesuits in China had the potential to become a major event in their respective intellectual histories.

In identifying the potential and actual consequences of this cultural encounter, it is important to take into account that scientific knowledge never exists in isolation but is always part of a larger system of knowledge with which it interacts. In fact, the transmission of scientific knowledge—between cultures as well as within

[2] A broad account of the development of science in China under Western influence is given in (Elman 2005). Different perspectives on the early modern knowledge transfer from Europe to China are offered in (Jami 1999; Huang 2005). This chapter is not concerned with knowledge transmission in the opposite direction, i.e., from China to Europe, which constitutes a topic of its own.

[3] See the various contributions to Parts 1 and 2 of this volume. For examples from the multi-millennial transmission of knowledge in the mathematical sciences throughout the Eurasian continent, including China, see, e.g, (Høyrup 1989; Dold-Samplonius et al. 2002).

a culture from one generation to the next—presupposes a body of basic non-scientific knowledge that the originator and receiver share. No science textbook, even the most basic one, is comprehensible in itself. In the case of intercultural exchange this fact immediately raises the question of where the shared knowledge that makes communication possible comes from. Are there human universals that may account for the development of shared structures of knowledge in different cultures? Is the shared knowledge the result of earlier cultural exchanges? Is it the result of independent parallel developments? The answers to these questions may be different for different forms of knowledge. Thus, one may assume that certain aspects of the elementary knowledge acquired by any individual in the process of ontogenesis are universal owing to the fact that they are constructed in the context of the individual's interaction with a physical environment whose basic properties are largely culture-independent. Further, it is obvious that the acquirement of practical knowledge through dealing with technology presupposes the existence of corresponding technologies in the culture under consideration. The existence of these technologies may be due to their import from another culture, to independent invention, or to any possible graduation between these two extremes.

The question of the origin of theoretical knowledge structures that are shared across cultures requires the issue of independent development versus knowledge transfer to be addressed on several levels, since theoretical knowledge results from reflection upon other forms of knowledge in the context of (mostly literal) traditions of argumentation. Thus, besides the question of the origins of the knowledge reflected upon, there is the question of the conditions for the emergence of traditions of argumentation and the transformation of these traditions through contact with (initially) foreign theoretical traditions. In this context it is important to note that in different cultures similar constellations of practical and theoretical knowledge may develop independently. In fact, there appears to be a case of such independent parallel development in ancient Greece and China, where similar mechanical technologies brought about similar theoretical insights (Renn and Schemmel 2006). This shall be outlined briefly here.

Before the formulation of any explicit theories of mechanics, similar mechanical devices were used in China and the West. An example of such a device is the shoulder pole, which has two containers hanging at each end and which was kept in equilibrium when being carried on one shoulder. The use of this device is attested in Greece for the fifth century BCE and can be argued to have existed in China in the third century BCE (Damerow et al. 2006, 4), but it may be assumed that it was invented much earlier. The earliest known texts of theoretical mechanics in ancient Greece and ancient China, the Peripatetic *Mechanical Problems* and a couple of sections in the so-called *Mohist Canons* (*Mojing* 墨經), were written independently at about the same time, around 300 BCE. Both texts contain statements that may be considered as precursors of the law of the lever and that resulted from the reflection on practical activities such as balancing the shoulder pole. Thus, for instance, in free translation, one of the so-called Canons of the Mohists contains the following explanation:

> A beam: if you add a weight to its one side, [this side] will necessarily hang down. This is due to the effectiveness and the weight matching each other. Level both sides up with each other, then the base [i.e. the heavy side] is short and the tip is long.[4]

Likewise, the Peripatetic *Mechanical Problems* contains the statement:

> The further that which moves the load is away from the fulcrum, the more it moves the load.[5]

While there is in fact a common core of mechanical knowledge in the earliest theoretical accounts on mechanics in China and in the West, and even the social context of their emergence displays similarities (a politically highly fragmented cultural realm in which specific cultures of disputation had developed), the particular conditions of the origin and the later fate of these theoretical accounts were quite different. Thus, Peripatetic mechanics directly reflects the invention of the balance with unequal arms and its identification with mechanical devices such as the shoulder pole.[6] In China, the balance with unequal arms was used possibly as early as the time of the Jin 晉 dynasty (265–420 CE), but its oldest attestations do not reach back to the time of the Mohists.[7] What is more important, in Greece the incipient theory of mechanics quickly developed into a comprehensive body of theoretical knowledge, prototypically represented in its theoretical and practical aspects by the works of Archimedes and Heron respectively. In China, by contrast, the theoretical tradition of the Mohists was soon interrupted by the autocratic regime of the Qin 秦 dynasty (221–206 BCE) from which it never recovered. It was only after the Jesuits' intervention in Chinese history of science that the ancient Chinese mechanical heritage was rediscovered.

The Chinese tradition of practical mechanics and technology, however, continued and flourished. Many centuries before the arrival of the Jesuits, various Chinese technologies like those of agriculture, textile and paper production, book printing and water transport were highly advanced. As was the case for European technology until well into early modern times, the technological development had largely taken place without the reliance on any kind of theoretical knowledge.

---

[4] "（衡）。加重於其一旁必捶，權重相若也。相衡， 則本短標長。" Section B25b in (Graham 1978, 387). The translation given here is based on joint work of a project group at the Max Planck Institute for the History of Science with William G. Boltz.

[5] "ἀεὶ δὲ πλέον βάρος κινεῖ, ὅσῳ ἂν πλέον ἀφεστήκῃ τοῦ ὑπομοχλίου ὁ κινῶν τὸ βάρος." (Aristotle, *Mechanical Problems*), 850b14–16 (Aristotle 1936, 354), modified translation.

[6] A balance with unequal arms is explicitly mentioned in problem 20 of the *Mechanical Problems*. An earlier attestation of the use of balances with unequal arms in Greece is found in Aristophanes' play *Peace*, see (Damerow et al. 2002, 95).

[7] For a discussion of different assumed dates for the earliest occurrence of the balance with unequal arms in China, see (Guo 1993, 29–30; Renn and Schemmel 2000, in particular 22–23).

But while in Europe branches of the mathematical sciences developed that were concerned with resource saving technologies like simple machines, this was not the case in China, where the mathematical sciences were mostly concerned with astronomy, numerology and harmonics (Sivin 1977, xiii).

Traditional Chinese mathematical texts are mostly written in the form of problems and prescriptive rules for their solution. They contain solutions to intricate problems, for example, to what today would be called systems of linear equations. The tradition also includes what may be called geometrical problems, but there is no science of geometry in the deductive style of Euclid's *Elements*. To what extent the Chinese algorithms represent proofs implying a tacit foundation in deductive reasoning is a controversial issue.[8]

Chinese mathematics is often said to have been in decline for centuries before the arrival of the Jesuits.[9] Indeed, many classical works of Chinese mathematics, such as Liu Hui's 劉徽 (fl. 263 CE) comprehensive commentary to the *Jiuzhang suanshu* 九章算術 [*Nine Chapters on the Art of Calculation*], were no longer available, and the thirteenth-century tradition of algebra had become obsolete (Needham 1988, Vol. III, 51). Nevertheless, there was an active tradition of arithmetics well into the time of the Jesuits.

An influential text of the period under consideration is the *Suanfa tongzong* 算法統宗 [*General Source of Computational Methods*] of 1592, compiled by the merchant Cheng Dawei 程大位 (1533–1606), who was a devoted collector of arithmetical knowledge. Interestingly, there are indications of European influence in this text that hint at a transmission of knowledge predating the Jesuit mission,[10] possibly from the Portuguese settlement in Macao (Needham 1988, Vol. III, 148).

Throughout the history of imperial China, astronomy was predominantly calendrical science in the service of the imperial court. In certain periods the pursuit of astronomy outside the court was even prohibited. A wealth of records document an unbroken multi-millennial tradition of astronomical observations, including observations of sunspots, comets, novae and supernovae. The calculation of the calendar included the prediction of the positions of the sun, the moon and the five planets, as well as of rare events like eclipses. While the calendrical calculations were not based on geometrical models of the heavenly motions, there are Chinese sources documenting simple geometrical conceptions of these motions.[11] In the Mongolian Yuan 元 dynasty (1206–1368), an Islamic Astronomical Observatory was established in addition to the traditional Chinese one, which still existed in the seventeenth century. An influence of Islamic astronomy on the Chinese tradition is arguably visible in the field of astronomical instrumentation, as the prominent

[8] See, for instance, (Cullen 1995; Chemla 2005).

[9] See, for example, (Needham 1988, Vol. III, 209; Martzloff 1997, 19–20).

[10] Consider, for instance, the problems in vol. 4 of the *Suanfa tongzong*, which arguably reflect knowledge of the law of the lever.

[11] Geometrical conceptions of the celestial motions are evident, for example, in Shen Gua's 沉括 (1031–1095) *Mengxi bitan* 夢溪筆談 [*Brush Talks From Dream Brook*], chapters 7 and 8 on astronomy (*Xiang shu* 象數), see (Gua 1997). For a German translation, see (Kuo 1997).

example of Guo Shoujing's 郭守敬 (1231–1316) instruments reveals (though no originals are extant).[12]

Besides these predominantly quantitative sciences, there were qualitative discussions of physical phenomena like magnetism and optical phenomena, and rich traditions of what may be called medicine, alchemy, astrology and geomancy (not forgetting the huge differences in the European traditions of the same name). They mostly drew from a common pool of natural philosophic concepts such as yin 陰 and yang 陽, and the Five Processes (*Wu xing* 五行), (Sivin 1977, xiii).

11.3 How Scientific Knowledge Came to Be Transmitted by the Jesuits

In the seventeenth and early eighteenth centuries European scientific knowledge was transferred to China almost exclusively by Jesuit missionaries. Not only did they represent by far the largest portion of missionaries in China throughout the time of their mission, their numbers ranging from four in 1590 to eighty-two in 1701,[13] with their education as well as their modes of defending, consolidating and propagating their faith, they were very well prepared to spread scientific knowledge.

Shortly after the formation of the order in the first half of the sixteenth century, the Jesuits had become the intellectual bridgehead of the Catholic Church in its struggle against Protestantism and a major tool for its own spiritual renovation. The Jesuits propagated an integrated Christian worldview in which natural philosophy was of outstanding importance as an ancillary science of theology. To disseminate knowledge and faith and to educate the next generation, they established a growing network of schools and colleges which stretched across Europe (Krayer 1991, 7). The pursuit of the mathematical sciences, which consisted of the *quadrivium* arithmetics, geometry, music and astronomy, and included practical sciences such as optics, geography and mechanics, became the speciality of the Jesuit order, even though its place in natural philosophy remained controversial within the Church and even within the order itself. While the proponents of a thorough mathematical education had only limited success in shaping the colleges' curricula (Krayer 1991, 24–42), they were able to establish a Jesuit tradition of science education through informal seminars and specialized academies. Most prominently, Christopher Clavius (1538–1612), mathematician, astronomer and leading contributor to the prestigious project of Gregorian calendar reform, established a school of mathematics at the Collegio Romano, the Jesuits' elite institution in Rome. Among the first Jesuits to obtain permission to settle on

[12] On Islamic astronomy in China during the Yuan and Ming dynasties, see (Yabuuti 1997); on instruments of Islamic origin, see in particular 14–17 and the discussion in (Dold-Samplonius et al. 2002, 340–342).

[13] For a statistic of missionaries in China from 1590 to 1815 according to their order or congregation, see (Standeart 2001, 307–8).

the Chinese mainland from 1583 on, several were trained at the Collegio Romano, most prominently Matteo Ricci (1552–1610), a pupil of Clavius.

While the Jesuits were thus well-equipped to spread scientific knowledge, their actual strategic use of science in China, which brought about the transmission of scientific knowledge, can only be understood as a reaction to Chinese culture.[14] In fact, nowhere in the world did the Jesuits make such systematic use of science to support their mission as they did in China where they were confronted with a highly developed, self-contained and stable cultural system—a nut they were ultimately unable to crack. Two aspects of the strategy for Christianization adopted by the Jesuits in this environment were crucial for the upcoming transfer of scientific knowledge: top-down evangelization and accommodation to Chinese culture.

Top-down evangelization. The Jesuits tried to convert members of the ruling class, ideally the emperor himself, in the hope that the subjects would then follow his example. While this strategy may have been inspired by European and, in fact, Japanese precedents (Gernet 1985, 16), it also paralleled the hierarchical structure of Chinese society. The ruling class of imperial China was at the same time its intellectual elite, a fact ensured for centuries by a tough examination system for selecting prospective bureaucrats. The Jesuits' main targets for conversion were thus highly educated scholar-officials.

Accommodation to Chinese culture. Apart from India, China was the only country in which the missionaries tried to adapt completely to the indigenous culture. The Jesuits learned the Chinese language and writing system and adopted the lifestyle of Chinese scholars. In the first years of the mission, Ricci had adapted to a Buddhist lifestyle but soon must have realized that in this way Christianity could at best achieve a position on a par with Buddhism and Taoism, which, from the viewpoint of orthodox Confucianism, would always remain potentially heterodox. In order to become the dominant faith, Christianity had to take on Confucianism.

The missionary effort in China thus led to the encounter of two intellectual elites, each representing a culture with a highly elaborate knowledge system and advanced technology. It was against this background that the wide-spread habit of colonialists and missionaries to impress indigenous peoples with all kinds of gadgets developed into a systematic use of scientific knowledge to attract the learned Chinese's attention and convince them of the high level of European civilization. In this development, corresponding traits between the two cultures further enhanced the transmission of knowledge, which, in the course of the mission, took place in three contexts: 1) personal contacts between Jesuits and Chinese scholars; 2) expert services rendered by Jesuits on commission of the Chinese state; 3) Jesuits' private tutoring of the Chinese emperor. In all three contexts, the Chinese

[14]For a concise description of the Jesuit strategy as a reaction to Chinese culture, see (Standeart 1999); for a comprehensive account of the Christian missions in China from late Ming to mid-Qing times, see (Standeart 2001, 113–906).

side did not act as passive receiver, but rather prompted or requested the transfer of knowledge against the background of an agenda of its own.[15]

Figure 11.1: The Jesuits Matteo Ricci, Adam Schall von Bell and Ferdinand Verbiest. From Johann Baptista du Halde, *Ausführliche Beschreibung des Chinesischen Reiches und der grossen Tartarey*, Rostock 1749, p. 93. Permission of the Max Planck Institute for the History of Science Library.

1. *Personal contacts between Jesuits and Chinese scholars.* In the early decades of the seventeenth century, Jesuits like Matteo Ricci, Sabatino de Ursis (1575–1620) and Giulio Aleni (1582–1649) succeeded in converting a few Chinese scholars—most prominently Xu Guangqi 徐光啟 (1562–1633), who later became Vice Minister in the Ministry of Rites and was the highest-ranking convert the Jesuit mission would produce[16]—and worked with them on rendering European knowledge in Chinese writing. Through the presentation of European technical and scientific achievements, the Jesuits hoped to arouse the interest in their teachings of a broader group of scholar-officials, and eventually also of the imperial court.[17] The Jesuits' expertise in mathematical and practical matters paralleled a growing concern for such matters among Confucian scholars toward the end of the Ming 明 dynasty (1368–1644). Serving a state that was becoming increasingly dysfunctional, they

[15] For an overview of the role of the different branches of the sciences in the Jesuit missionary effort, see (Standeart 2001, 689–808).
[16] On different aspects of Xu Guangqi's life and work, see (Jami et al. 2001).
[17] Ricci's strategic use of science may have been modeled partly on the experience he had made with his famous world map of 1584, which had generated wide interest among Chinese scholars and provided him with many important acquaintances; see, for example, (Gernet 1985, 20–21).

more than once interpreted the neo-Confucian term *shixue* 實學, which may be translated as 'solid studies,' in the sense of practical studies which they pursued with the aim of improving statecraft. Together with the Jesuits, but also on their own, they published books on surveying, geography, water control, military technology, mechanical devices and astronomy. But also works of 'pure' mathematics were praised as a necessary basis for mastering practical affairs, as is exemplified in Xu's preface to the *Jihe yuanben* 幾何原本 (1607), the Chinese translation of the first six books of Euclid's *Elements* which he had prepared together with Ricci (see Figure 11.2). After the dynastic change in 1644, such close private co-operation between Jesuits and Chinese scholars became the exception, while the Jesuits became more successful in working for the imperial court.[18]

2. *Expert services on commission of the state.* The converted Chinese associates of the Jesuits not only urged their foreign friends to publish on scientific and technical matters, but also sought to have them apply their expertise directly for the good of the dynasty. The missionaries, on the other hand, by offering their services could hope to make themselves indispensable in China and to come closer to courtly circles. The three main fields in which Jesuit expertise matched Chinese demands were astronomy, military technology and geography.

   Astronomy. The need to revise the imperial calendar had been perceived by Chinese officials since the end of the sixteenth century. The imperial calendar was of crucial importance for the state. It was officially issued by the emperor and every dynasty (and sometimes single emperors) issued a new one at the beginning of their reign. The fate of an emperor or dynasty could depend upon the reliability of the calendar: mismatches between predicted and occurring phenomena were interpreted as bad omens and could incite rebellion against the ruling family. Ricci had understood the importance of scientific expertise, especially in astronomy, for the Jesuit mission and at an early stage had called on his European home base to send more missionaries trained in the sciences. These were Johann Adam Schall von Bell (1592–1666), Johann Schreck (latinized Terrentius, 1576–1630) and Giacomo Rho (1593–1638), who arrived together with Nicolas Trigault (1577–1628) when he returned to China in 1618. In 1629, without being given office, they began to revise the calendar under the supervision of Xu Guangqi at the newly founded Calendar Office (*Liju* 曆局), where they had more than twenty Chinese collaborators. After the dynastic change from Ming to Qing 清 (1644–1911), the Jesuits were given office, even that of the head of the

[18] A major cause for the retrogression of the Jesuits' missionary success among the Chinese elite can be found in the change of intellectual climate in seventeenth-century China, from the perception of crisis and exceptional openness to foreign ideas in the first decades of the century to the concentration on the domestic classical traditions under a foreign but stable rule at its closure; this development is sketched in (Wills 1994).

36 EVCLID. GEOM.

PROBLEMA I.

PROPOSITIO I.

SVPER data recta linea terminata triangulum æquilaterum conſtituere.

IN omni problemate duo potiſſimùm ſunt conſideranda, constructio illius, quod proponitur, & demonſtratio, quâ oſtenditur, conſtructionem rectè eſſe inſtitutam. Vt quoniam primum hoc problema iubet conſtituere triangulum æquilaterum ſuper data recta linea terminata quacunque, ita vt linea recta propoſita ſit vnum latus trianguli. (Tunc enim figura dicitur conſtitui ſuper recta linea, quando ipſa linea efficitur vnum figuræ latus) idcirco primum oportet conſtruere ex principiis conceſſis triangulum aliquod, deinde demonſtrare, ipſum eâ ratione conſtructum, eſſe æquilaterum, hoc eſt, habere omnia tria latera inter ſe æqualia. Quod idem in alijs problematibus perſpici poteſt. Hæc etiam duo reperiuntur ferè in omni Theoremate. Sæpenumerò enim vt demonſtretur id, quod proponitur, conſtruendum eſt, atque efficiendum prius aliquid, ceu manifeſtum erit in ſequentibus. Pauca veró admodum ſunt theoremata, quæ nullam requirant conſtructionem.

Sit igitur propoſita recta linea terminata AB, ſuper quam conſtituere iubemur triangulum æquilaterum. Centro A, & interuallo rectæ AB, a deſcribatur circulus CBD: Item centro B, & interuallo eiuſdem rectæ BA, alius circulus deſcribatur CAD, ſecans priorem in punctis C, & D. Ex quorum vtrouis, nempe ex C, b ducantur duæ rectæ lineæ CA, CB, ad puncta A, & B; Eritque ſuper rectam AB, conſtitutum triangulum ABC, hoc eſt, figura rectilinea contenta tribus rectis lineis. Dico, hoc triangulum ita conſtructum neceſſariò eſſe æquilaterum. Quoniam rectæ AB, AC, ducuntur ex centro A, ad circumferentiam circuli CBD, c erit recta AC, rectæ AB, æqualis: Rurſus quia rectæ BC, BA, ducuntur ex centro B, ad circumferentiam circuli CAD, erit recta BC, rectæ BA æqualis. Tam igitur AC, quàm BC, æqualis eſt rectæ AB. d Quare & AC, BC, inter ſe æquales erunt, atque idcirco triangulum ABC, erit æquilaterum. Super data ergo recta linea terminata, &c. Quod faciendum erat.

a 3. pet.
b 1. pet.
c 15. def.
d 1. pron.

SCHOLIVM.

VT autem videas, plures demonſtrationes in vna propoſitione conti-

古今算學叢書

賜同進士出身記名總理各國事務衙門章京內閣中書舍人加三級臣劉鐸編校

幾何原本第一卷 本篇論三角形 計四十八題

泰西利瑪竇口譯

吳淞徐光啓筆受

第一題

于有界直線上求立平邊三角形

法曰甲乙直線上求立平邊三角形先以甲爲心乙爲界作丙乙丁圜次以乙爲心甲爲界作丙甲丁圜兩圜相交于丙于丁末自甲至丙丙至乙各作直線卽甲乙丙爲平邊三角形

論曰以甲爲心至圜之界其甲乙線與甲丙甲丁線等以乙爲心則乙甲線與乙丙乙丁線亦等何者凡爲圜自心至界各線

幾何原本 卷一 三 象數第二

Figure 11.2: First proposition of the first book of Euclid in Christopher Clavius' influential edition (1607; first published in 1574) and the Chinese adaption and translation by the Jesuit Matteo Ricci and his Chinese collaborator Xu Guangqi (1865; first published in 1607). Permission of the Max Planck Institute for the History of Science Library.

Astronomical Bureau (*Qintianjian* 欽天監) which was first held by Schall, and, after a five year intermission, by Ferdinand Verbiest (1623–1688). It only ceased to be in European hands in 1826.[19]

Military technology. The late-Ming-dynasty state had a urgent need to improve its military technology since it was threatened from the inside by peasant rebellions and from the outside by Manchu attacks. Cannons based on European models had been cast by the Chinese since 1519, but the

[19]The long-lasting European directorship of the Astronomical Bureau did not bring about a continuing transfer of European scientific knowledge to China. As the Europeans' role in the Astronomical Bureau became increasingly institutionalized, one can discern a "progressive bureaucratic insulation of Western computational techniques as a routinized and circumscribed function of the Astronomical Bureau" (Porter 1980, 71), which increasingly distanced the Europeans' intellectual activities from the propagation of new developments within European science.

seventeenth-century Portuguese specimens, whose import from Macao together with Portuguese gunmen was instigated by Xu Guangqi and Li Zhizao 李之藻 (1565–1630), turned out to be superior. In the last years of the dynasty, Schall cast at least twenty pieces of artillery in commission of the state. After the dynastic change, Verbiest cast nearly 500 cannons which were used in the conquest of Hunan 湖南 and Taiwan 臺灣 and in putting down the rebellions that beset the young Qing dynasty.

Geography. As Ricci had done before him, Verbiest in 1678 called on his order to send more personnel competent in mathematics and astronomy to join the mission in China. This was answered by the deployment of appointed correspondents of the Académie Royale des Sciences through Louis XIV (r. 1643–1715), "the King's mathematicians," who arrived in China in 1685. Besides their work in astronomy and mathematics in the narrower sense, they were able make use of another practical science in which the Jesuits excelled: they became involved in a great surveying project. The rapid expansion of the Qing empire (and not least the fear of rebellion) made an accurate geographical representation of its territories a matter of state interest. The Kangxi 康熙 emperor (r. 1662–1722) commissioned a survey of the entire Chinese empire, which was supervised by French Jesuits and undertaken from 1708 to 1717. The emperor's interest in mapping the empire coincided with the Jesuits' interest in mapping the countries they were attempting to Christianize. Later in the eighteenth century during the Qianlong 乾隆 reign (1736–1795) Jesuits were commissioned with further surveying projects.

3. *Tutoring the emperor.* The Jesuits had long attempted to capture the attention of the imperial court, but it seems they were not granted an audience during the Ming dynasty (Standeart 2001, 492–495). It was only after the dynastic change in 1644 that the Jesuits were finally able to establish closer relations to the court and to the emperor himself. Thus, Schall became the tutor of the Shunzhi 順治 emperor (r. 1644–1661) who was only twelve years old in 1651 when he began to rule by himself. Later, the Kangxi emperor, who was highly interested in mathematics and astronomy but also in various other aspects of European culture, was tutored by Verbiest and by some French Jesuits.

All three contexts of knowledge transmission yielded books in Chinese on European science and technology (and the context of tutoring the emperor even a few in Manchu); in the course of the seventeenth century the Jesuits and their supporters published nearly 600 books, an estimated several dozen of them on European science and technology.[20] All three contexts yielded the manufacturing of European-style scientific instruments, most prominently Verbiest's large astronomical instruments which he produced for the Beijing observatory (including an

[20]For statistics and references to bibliographies of the Jesuit's scientific writings in China, see (Peterson 1973, 296; in particular note 5; Standeart 2001, in particular 600 and 631).

ecliptic armillary sphere and a celestial globe), but also telescopes. And all three contexts involved the direct teaching of certain topics of European science to the Chinese, whether individual late-Ming scholars who actively sought out the Jesuits, prospective Chinese co-workers in the courtly institutions, or a Qing emperor.

11.4 Constraints of the Jesuit Context of Knowledge Transmission

In order to fulfill their mission the Jesuits had to reconcile two incompatible political-religious schemes, i.e., schemes with different dividing lines between politics and religion. In the European scheme religion had far-reaching implications on moral and political life, but at the same time was counteracted by the secular powers of monarchy. In the Chinese scheme the moral and the political were domains of state orthodoxy (or 'state-religion') with no great counteracting power, while the various religions and sects were tolerated as long as they did not interfere with the state monopoly in political and moral affairs. Thus, from the perspective of the Chinese state, the Jesuits might have been allowed to propagate their religion for the sole purpose of self-cultivation, on a par with Buddhism, Taoism and popular religion. From the perspective of the Roman Church, on the other hand, such subordination to a non-Christian moral system, which prescribed ritual actions for ancestor worship and the cult of Confucius, could not be accepted.

This incompatibility explains the precarious situation of the Jesuits during the entire period of their mission. Matteo Ricci established a delicate compromise by declaring crucial components of Confucianism to be compatible with the Christian faith and by tolerating the performance of Confucian rituals by Chinese Christian converts. The careful search for compromise was continued by most later Jesuits, but it was constantly endangered by attacks from two sides: missionaries of orders other than the Jesuit and eventually the Church in Rome who feared the corrosion of the Christian faith through the Jesuits' concessions; and Chinese scholars and officials and eventually the imperial court who perceived the missionaries as intruding into the sphere of the state.

The conflict repeatedly hampered the transmission of science and eventually brought it to an almost complete halt. Thus, in the so-called "Nanjing incident" of 1616, the central government's first action against the missionaries, the Vice-Minister and acting Minister of Rites, supported by other officials, accused the missionaries in the two administrative centers of the empire, the northern and southern capitals Beijing 北京 and Nanjing 南京, of violating Confucianism and put them on trial. The four missionaries active in the two capitals were expelled to Macao and the remaining eight retired from the public scene. (At that time, a total of twelve missionaries, all Jesuits, were working in China.) In consequence of this incident, from 1616 to 1622 all publication activities of the Jesuits, including those on science, were halted (Hummel 1943, 453; Peterson 1973, 296).

From the mid-seventeenth century, the Roman Church intervened through papal decrees in the controversy that took place between the different orders operating in China about the proper attitude toward the Chinese rites (and also about how to render central Christian concepts such as 'God' in Chinese).[21] In 1704 the pope condemned Chinese rites such as sacrifices to ancestors or to Confucius (and forbade the use of much of the Chinese Christian terminology Ricci had introduced). In 1706 the Kangxi emperor issued the order that all missionaries would have to follow 'the rules of Matteo Ricci' or leave the country. After the reiteration in 1715 of the papal decree condemning Chinese rites and the intervention of papal legates in China, who in the eyes of the Kangxi emperor were interfering in China's internal affairs, the emperor finally condemned the Christian activities, declaring that their religion

> [...] actually does not differ from the heterodox and inferior talk of Buddhists and Taoists; it is the acme of unlawful nonsense. Henceforth Westerners must not be allowed to practice their religion in China. We may as well prohibit it, so as to avoid a lot of trouble.[22]

The prohibition of Christianity was enacted by the Yongzheng 雍正 emperor (r. 1723–1735) in 1724. While Christianity lingered on in the provinces and Jesuits continued their work as foreign experts at court, this decision deprived the missionaries of the perspective to win the Chinese elite and the emperor over to Christianity and thus destroyed what had been the conditions for the emergence of the transmission of European scientific knowledge to China. This may be taken as marking the end of any vivid form of such transmission in the early modern period.

But the transmission of science was not just the victim of a political-religious struggle. Chinese opposition to the introduction of European science in fact played a major role in the attacks on the Jesuits. This is especially the case for their activities in astronomy owing to the close relation of calendrical science with state orthodoxy. There is evidence that it was the attempt of the Jesuits and their Chinese convert associates to promote a calendar reform based on European astronomy that alarmed the officials into taking action against the Jesuits, thus initiating the Nanjing incident. And a central accusation leveled against the Jesuits was their alleged dismissal of the basic Confucian relationships like that between sovereign and minister through their astronomical theories. In Chinese traditional representations, the relationships between the sovereign, his wife, his administrators and the common people were correlated with those between the heavenly bodies, while Aristotelian cosmology separated them by dividing the heaven into several orbs.[23]

---

[21] On the 'rites controversy,' see, for example, (Standeart 2001, 680–688).
[22] Imperial autograph comment, cited after (Standeart 2001, 498).
[23] Several heavens *tian* 天, as the spheres were rendered in Chinese; (Gernet 1985, 61; Standeart 2001, 510).

The Jesuits' heading of the Astronomical Bureau set their science directly in the context of Chinese state orthodoxy. Their performance was judged not only by the precision of their predictions, but also by how they integrated traditional elements of Chinese calendar making in the context of their new methods of calculation, and how they performed other rituals that belonged to their duties such as the selection of auspicious times and places for imperial funerals. This made the Jesuits and their science particularly vulnerable to attacks by conservative officials. Thus, in the Calender Case of 1664, Schall was accused of selecting an inauspicious date and site for a burial. In April 1665 Schall and seven officials of the Astronomical Bureau were sentenced to death. Schall was later pardoned while five Chinese Christian officials were executed.[24]

11.5 The Impact of European Scientific Knowledge on the Chinese Tradition

Despite the fact that the transmission of scientific knowledge was not the primary concern of the missionaries, they were, in a way, more successful in transmitting science than in transmitting their faith. At least among the learned Chinese, their science aroused much more interest and reception than did their religion. But also European science was not received as a whole. Outside the small circle of their convert associates, the view was widely held that the Europeans were good at calculations but bad at 'fathoming the principles' (*qiongli* 窮理). Thus, what was presented by the Jesuits as integral parts of one worldview (mathematics, Aristotelian philosophy and Christianity) was dissected and the parts were received with very different intensity. European knowledge was largely perceived as complementing the domestic traditions, as may be illustrated by a statement of Zhou Ziyu 周子愚, the Vice Director of the Astronomical Bureau in the mid-1610s, who wanted European scientific works to be translated and be "taken to supplement the [Chinese] basic canons."[25] Accordingly, the transmission was most effective in the domains of mathematics and mathematical astronomy.

Mathematics. Western methods of written calculation were introduced and in learned circles replaced the use of the abacus, which had earlier replaced traditional Chinese rod calculation. Trigonometric and logarithmic tables, as well as new instruments such as Napier's bones and Galileo's proportional dividers came into use. Hybrid works, merging Chinese and European mathematical traditions were compiled, such as *Shuli jingyun* 數理精蘊 [*Collected Basic Principles of Mathematics*] which was first published in 1723 at the newly created imperial Academy of Mathematics (*Suanxue guan* 算學館) and served as a textbook. It was realized exclusively by Chinese mathematicians, but integrated revised lecture manuscripts written by the Jesuits when tutoring the emperor. In this book, European and Chinese methods for solving the same mathematical problems are presented side

[24] On the 1664 Calender Case, see (Chu 1997).
[25] Cited after (Engelfriet 1998, 331).

by side and, besides the traditional Chinese scheme of problem and method of solution, definitions, geometric constructions and other elements that reveal the influence of Euclid can be found (Jami 1994, 233).[26]

Astronomy. In the calendrical astronomy of the imperial court, Western methods of calculation were established, but without teaching the Chinese the astronomical and physical theories on which they were founded. Thus, in the eighteenth century star catalogs were updated by relying on European data and the ephemerides were calculated on the basis of Newtonian theory, which was not introduced to China before the second half of the nineteenth century. There was an increasing interest in astronomy outside the imperial court. Scholars discussed geometrical world systems like the Ptolemaic (geocentric) or the Tychonian (geocentric, but with planets revolving around the sun). They synthesized Chinese and European ideas on cosmology (Henderson 1986)[27] or integrated European knowledge on astronomy, like the existence of Jupiter's satellites, into a basically traditional Chinese framework, for example, in the work of Jie Xuan 揭暄 (1613–1695).[28]

While large portions of European scientific knowledge were thus integrated into the Chinese corpus, the Chinese image of scientific knowledge as well as its institutional and social embedding remained largely unaltered. Verbiest's bold attempt to introduce Aristotelian philosophy into the state examination scheme failed, as did the French Jesuits' plans to create in China an academy on a par with the French Académie Royale des Sciences. Instead Verbiest and the French Jesuits became servants of the Chinese institutions.[29]

Still, the massive influx of foreign knowledge seems to have appeared threatening enough to the Chinese to necessitate a justification for its use, in particular in the context of the imperial calendar. A widely employed strategy was the advocation of the theory of the "Chinese origin of Western science" (*Xixue zhongyuan* 西學中源). It implied that the Europeans were the heirs of an ancient Chinese math-

[26] Further works of Chinese mathematics which reveal an influence by Western mathematics are discussed in (Jami 1996).

[27] Examples are the syncretistic world systems of Mei Wending 梅文鼎 (1633–1721), who discussed the physical reality of the (possibly interpenetrating) spheres and the outermost immobile sphere as base of the prime mover, and of Wang Xishan 王錫闡 (1628–1682) who devised his own Tychonic system (Henderson 1986, 131–132).

[28] Chen Yue, personal communication. Nathan Sivin has argued that the Chinese scholars' negligence of the Copernican worldview was due to the fact that the Jesuits' early presentations of it were misleading, while the later correct presentation then contradicted their earlier statements (Sivin 1973, 103 and *passim*). From this perspective, the early failure to introduce Copernicanism to China appears to be a mere consequence of the constraints of the Jesuit context of knowledge transmission. In view of the fact that in Europe, too, a 'correct' presentation of Copernicanism was not readily available and that Copernicanism prevailed despite (and in a way even due to) the fact that it contradicted earlier ideas, it seems obvious, however, that more profound differences between the European and the Chinese knowledge systems at the time and their respective social embedding must be invoked to explain the different fates of Copernican cosmology in the two cultures. Cf. note 44.

[29] For the case of the French Jesuits, see (Jami 1994, 240).

ematical tradition which had allegedly spread throughout the world in the time of the Three Dynasties (roughly the first two millennia before the Common Era), but while surviving in the West it had been destroyed in China by the burning of books in the Qin dynasty (221–207 BCE) (Wong 1963, 38–39).

A major result of the introduction of Western scientific knowledge to China was a turn to the philology of Chinese science[30] which was, however, only one facet within a general trend to philology of early Qing scholars.[31] Chinese scholars searched for traces of an indigenous tradition in the sciences and were able to rediscover and reconstruct many classical writings of the Chinese tradition. The philology of Chinese mathematical texts became the main occupation of eighteenth-century Chinese mathematicians.

Summing up, in early modern times the Chinese were highly selective in their reception of Western science. They made use of mainly those aspects of Western knowledge that were useful for what they did anyway (calendar making, surveying,[32] calculating, and so forth). Branches of knowledge that were further removed from the Chinese traditions, like theoretical mechanics or syllogistic logic, did not make a lasting impact before the end of the nineteenth century. While the scientific knowledge the Jesuits brought with them enriched the body of Chinese theoretical knowledge, it hardly changed their image of knowledge and the way science was done in China.[33] The Jesuit introduction of science also did not result in an unbroken tradition of science exchange between Europe and China. In consequence, symbolic algebra and the calculus remained unknown in China before the second half of the nineteenth century. In view of the central role these new branches of mathematics played in the further development of European science in the eighteenth and nineteenth centuries, especially in physics, astronomy and mathematics proper, it becomes obvious that the ignorance on the part of the Chinese relates to the decoupling of Chinese science from almost all of the developments that characterize European modern science.[34]

[30] See, for example, (Sivin 1973, 72).

[31] See (Elman 1984, in particular 62–64 and 79–85).

[32] For example, in the *Celiang fayi* 測量法義 [*The Meaning of Methods of Measurement*] of 1608, which discusses "measurement and survey problems [...] in terms of Euclidean geometry; it also describe[s] the instruments used and their construction" (Jami 1996, 179).

[33] For the concept of images of knowledge, see Elkana (1981). See also chapters 1 and 9.

[34] This assessment stands in stark contrast to Joseph Needham's claim that around 1600 "there ceases to be any essential distinction between world science and specifically Chinese science," (Needham 1988, Vol. III, 437). In view of the differences that remained between the two science traditions as described here, and the difficult processes of the transmission of European scientific knowledge to China beginning in the second half of the nineteenth century, it is difficult to imagine what Needham's statement could mean. For a recent critical review of Needham's legacy, see (Schäfer 2010).

11.6 The Transformation of Knowledge in the Process of Transmission

When European science was transmitted to China, it was not just its immediate context changed, as the case of European astronomy in the service of the Chinese state exemplifies, but also the representation of scientific knowledge and indeed the content of science itself. This transformation was due mainly to the assimilation of this knowledge to Chinese knowledge traditions, an assimilation that becomes visible from the fact that European mathematical science and natural philosophy were presented as instances of *gewu qiongli* 格物窮理, a neo-Confucian term that may be translated as "the investigation of things and the fathoming of principles" which however had a distinct moral connotation.[35]

But the transformation already begins with the translation of European scientific writings into the Chinese language. There is, in fact, no evidence that Chinese scholars attempted to study the several thousand European books brought to China by the Jesuits in their original languages. The books on European science and technology written by the Jesuits and their Chinese collaborators were translations of European works, or collections of translations of passages from several European works, augmented with texts and passages specially prepared for the Chinese readers. The procedure of translation was mostly the one followed in earlier centuries in what may be called the greatest import of foreign knowledge into the Chinese culture before the introduction of Western science: the introduction of Buddhism. The translation was done in two steps: a Jesuit explained the original text in spoken Chinese (orally interpreted, *kouyi* 口譯) and a Chinese scholar wrote it down in literary Chinese (received or transmitted with the brush, *bishou* 筆受 or *bishu* 筆述). One may surmise however that the actual division of labor was not so clear-cut and that the translation of more difficult passages was preceded by discussions and a search for appropriate words.

We will not discuss here the preposterous thesis that the Chinese language, due to its structure or any peculiarity of its grammar such as the absence of inflection, was unsuited for the transmission of European science because, for instance, it was too ambiguous.[36] The actual problems for the translators were of lexical rather than grammatical nature. For most of the words that occurred in the European texts and that make up everyday language there were unproblematic Chinese counterparts. Clearly, the advanced state of Chinese technology facilitated the translation of texts on practical sciences like technical mechanics, water works or surveying. For the translation of the more theoretical terms, the translators had three options: they could either transliterate a term phonetically, thus treating the word like a place-holder that takes on meaning through explanation or usage; they could invent a new Chinese term that was composed of characters that disclose something about its meaning; or, finally, they could use a term from the

[35] See, for instance, (Henderson 1984, in particular 126 and 151).
[36] The claim of ambiguity is critically discussed, for instance, in (Wardy 2000, 6–10).

Chinese knowledge tradition that had a meaning somewhat similar to the term to be translated. The two latter options (which coincide in the case of monosyllabic terms) were by far the most prevalent.

This practice immediately raises the question of the degree to which the transferred knowledge was altered owing to the different connotations of the Chinese terms. Were there, for instance, connotations of the word *li* 力, which was often used to represent the Latin *vis* (force), that changed the meaning of statements in mechanics?[37] Did the use of the Chinese terms *shu* 數 and *du* 度 for number and magnitude, respectively, lead to misunderstandings about the separation of number and magnitude in the European tradition, since *du* originally means 'measure' and is closely associated with the practice of surveying?[38] These questions can only be answered by detailed studies of the usage and understanding of particular terms.[39] It is clear, however, that the impact of such connotations on the understanding of a new technical term is potentially greater the less the term's meaning is fixed within a network of other technical terms in the translated text, and the more the more the meaning of the source term is obtained from contexts external to the source text.[40]

There are in fact many cases in which the contexts given by the Chinese and European traditions were consciously merged, thereby producing concepts of double origin. Thus, while in their letters to Europe the Jesuits ridiculed the Chinese doctrine of the Five Processes as aberrant and absurd,[41] they integrated the Chinese idea that water conquers fire into their exposition of the natural place of the Aristotelian elements: fire strives to its natural place above; as soon as it is put under water, which is not its natural place, it is attacked by water and goes out. This merger was facilitated by the fact that in both traditions fire goes up while water goes down, a coincidence that may reflect shared basic human experiences of upward and downward motions. The argument is found in the *Yuanxi qiqi tushuo luzui* 遠西奇器圖説錄最 [*A Record of Selected Illustrations and Descriptions of Remarkable Machines from the Far West*] of 1627. It is repeated in Verbiest's *Qiongli xue* 窮理學 [*Cursus philosophicus*] which indicates that it was

[37] This question is tentatively discussed in (Damerow et al. 2006, 2–3). For a selection of passages from various ancient Chinese sources containing the term *li* 力, see (Zou 2006).

[38] See (Engelfriet 1998, 140).

[39] For discussions of representations of Western knowledge in Chinese terms focusing on the nineteenth and early twentieth centuries, cf. (Lackner et al. 2001).

[40] A furthergoing discussion of early modern translations of mechanical terms into Chinese is found in (Amelung 2001; Schemmel in press).

[41] Thus, relating the Chinese doctrine to the Aristotelian four elements, Ricci writes in a letter from 1595: "By adding metal and wood, and omitting air, they [i.e. the Chinese] count five elements (instead of four)—metal, wood, fire, water and earth. Still worse, they make out that these elements are engendered the one by the other [...]." Cited after (Needham 1988, Vol. III, 439).

made consciously rather than accidentally, possibly with strategic intent to blur the distinctions between the two knowledge traditions.[42]

The marginalization of deductive structure is another crucial transformation in the representation of knowledge that occurred in the early modern transfer of European scientific knowledge to China. The deductive organization of knowledge by means of definitions, postulates, axioms, theorems and proofs was a central aspect of science in the European tradition. Taking Euclid's *Elements* as its primary example, the tradition was followed well into modern times with a large part of the works of early modern science—including outstanding examples such as the Latin part of Galileo's *Discorsi* and Newton's *Principia*—more or less successfully copying this structure. The Chinese translation of the first six books of Euclid's *Elements* did indeed reproduce its deductive structure. However, the book, though praised by some Chinese scholars for its accurate style of argumentation, did not become a model in the Chinese tradition, not even in the case of geometry.[43] Other obvious occasions for the deductive presentation of scientific knowledge were not embraced. Thus, the first chapter of *Yuanxi qiqi tushuo luzui* contains a series of theorems taken from Simon Stevin's book *De beghinselen der weeghconst* of 1586, but presents them under omission of the proofs (Zhang et al. 2008, 92–119; Schemmel in press).

11.7 The Encounter of Two Systems of Knowledge

This discussion of the transmission of scientific knowledge from Europe to China in the early modern period has revealed a wide variety of factors—from epistemic to political—that influenced the consequences of the transmission. Despite their disparity they all originate in what may be described as the encounter of two systems of knowledge, each with its own distinct institutional and social embedding. As we have seen, what knowledge was actually transmitted and how this was transformed in the process of transmission was largely determined by the compatibilities and incompatibilities that existed between the two knowledge systems.

The transfer of European scientific knowledge to China was brought about by specific constellations of interests on both sides: the European (Jesuit) and the Chinese. The intellectual, political and religious conditions that made the knowledge transfer possible served, at the same time, as restrictions that hampered and occasionally even endangered its continuation. These conditions changed over

[42] The passage in the *Yuanxi qiqi tushuo luzui* reads: "For every body, if it is not at its [natural] place then this is necessarily contrary to [its] nature and other bodies can attack it. Therefore, to approach their respective natural place is what all bodies strive after. For example, fire naturally flames upwards. If you make it enter water then this is not [its] natural place and it will be extinguished immediately." (每物不在其所，則必與性相反，且別物得以攻之。故各就本所乃各物之所喜向也。假如火本炎上，使之入水，則非本所，便就滅息。) *Yuanxi qiqi tushuo luzui*, chapter one, section 23, see (Zhang et al. 2008, Vol. 2, 62). For the relevant quotation from the *Qiongli xue*, see (Yin 2006, 135).

[43] See, for example, (Martzloff 1980).

time during the Jesuit mission in China and by the mid-eighteenth century, the transfer of European scientific knowledge to China had come to a virtual halt.

The encounter resulted in a selective adoption of European scientific and practical knowledge and its assimilation to Chinese knowledge traditions, which to a large extent was shaped by the requirements of the Chinese imperial state. There were farther-reaching attempts at an integration of European scientific knowledge with Chinese traditions of natural philosophy and cosmology. These remained local endeavors, however, and did not bring about a new dynamics of knowledge production comparable to that in Europe.

The dynamics in the early modern European knowledge system came along with a high degree of instability. The science brought to China by the Jesuits was part of a knowledge system in transition and was itself in flux. It combined various partly incompatible knowledge traditions, such as Aristotelian philosophy, Archimedean mechanics and Euclidean mathematics, and had to integrate a growing body of practical knowledge originating from the technological developments of the time. The theoretical interpretations of the new practical experiences increasingly forced the emerging group of engineer-scientists into opposition to a worldview advocated by the Church that merged Aristotelian with biblical ideas. It was only through a reorganization of early modern society that the tensions inherent in early modern science and its cultural embedding could be eased.

The Chinese knowledge system at the time of the Jesuit intervention, by contrast, must be considered as highly stable. While a crisis was perceived toward the end of the Ming dynasty, the system recovered stability in the early Qing period. Notwithstanding the transformations of Chinese scholarship that took place during the seventeenth century, the internal structure of the knowledge system and its social and institutional embedding was at no point in the development subject to negotiation, as its quick adoption by the Manchu rulers conspicuously testifies.[44]

Thus in early modern times it was the unstable knowledge system of Europe that collided with the stable knowledge system of late traditional China. By the late nineteenth century the situation had completely reversed: the stable knowledge system of modern science with its solid embedding in an industrialized society

[44] At this point, it becomes particularly clear that the question of why the success of the transmission was so limited is closely related to Needham's classic question of why China did not develop modern science by itself (see, for example, (Needham 1969, 16); for critical reviews of Needham's question that appreciate its heuristic value, see (Graham 1971; Sivin 1982)). While any attempt to answer Needham's question lies outside the scope of the present chapter, it seems obvious that questions concerning the stability of the knowledge system are relevant, just as they are relevant to the problem of knowledge transmission from the West. Examples of such questions are: What practical knowledge was needed in centralistic China in comparison to Europe with its many competing political centers? How did new practical knowledge challenge traditional theoretical conceptions of the cosmos? And to what extent was there a power struggle between different strata of society in the context of which questions of natural philosophy and cosmology could have acquired a revolutionary potential? For the European case cf. (Lefèvre 1978, in particular 75–79). See also the discussion in chapter 9.

collided with the collapsing system of the Chinese elite whose inferiority had, in their own eyes, been proven by the military defeats at the hands of Japan and the West.

Acknowledgments

For helpful discussions I would like to thank Peter Damerow, Jürgen Renn, Joachim Kurtz, Dagmar Schäfer, Martina Siebert, Bill Boltz, Rivka Feldhay and Hans Ulrich Vogel. A large part of my work on Chinese science has been carried out in the context of joint research in the cooperative Partner Group framework of the Chinese Academy of Science and the Max Planck Society (2001–2006) and I would like to thank Zhang Baichun, Tian Miao, Zou Dahai and the other members of the Partner Group for the collaboration.

References

Amelung, I. (2001). Weights and Forces: The Reception of Western Mechanics in Late Imperial China. In M. Lackner, I. Amelung, and J. Kurtz (Eds.), *New Terms for New Ideas: Western Knowledge and Lexical Change in Late Imperial China*, Volume 52 of *Sinica Leidensia*, pp. 197–232. Leiden: Brill.

Aristotle (1936). *Minor Works: On Colours. On Things Heard. Physiognomics. On Plants. On Marvellous Things Heard. Mechanical Problems. Of Indivisible Lines. Situations and Names of Winds. On Melissus, Xenophanes, and Gorgias*, Volume 307 of *The Loeb Classical Library.* Cambridge, MA: Harvard University Press.

Chemla, K. (2005). The Interplay between Proofs and Algorithm in 3rd Century China. In P. Mancosu, K. F. Jørgensen, and S. A. Pedersen (Eds.), *Visualization, Explanation and Reasoning Styles in Mathematics*, Volume 327 of *Synthese Library*, pp. 123–145. Dordrecht: Springer.

Chu, P. (1997). Scientific Dispute in the Imperial Court: The 1664 Calender Case. *Chinese Science* (14), 7–34.

Cullen, C. (1995). How Can We Do the Comparative History of Mathematics?: Proof in Liu Hui 劉徽 and The Zhou Bi 周髀. *Philosophy and the History of Science: A Taiwanese Journal 4*(1), 59–94.

Damerow, P., J. Renn, S. Rieger, and P. Weinig (2002). Mechanical Knowledge and Pompeian Balances. In J. Renn and G. Castagnetti (Eds.), *Homo Faber: Studies on Nature, Technology, and Science at the Time of Pompeii*, Volume 6 of *Studi della Soprintendenza Archeologica di Pompei*, pp. 93–108. Rome: L'Erma di Bretschneider.

Damerow, P., J. Renn, and M. Schemmel (2006). The Transformation of Mechanical Knowledge. An Introduction. In B. Zhang and J. Renn (Eds.), *Transformation and Transmission: Chinese Mechanical Knowledge and the Jesuit Intervention*. Preprint 313. Berlin: Max Planck Institute for the History of Science.

Dold-Samplonius, Y., J. W. Dauben, M. Folkerts, and B. van Dalen (Eds.) (2002). *From China to Paris: 2000 Years Transmission of Mathematical Ideas*, Volume 46 of *Boethius*. Stuttgart: Steiner.

Elkana, Y. (1981). A Programmatic Attempt at an Anthropology of Knowledge. In E. Mendelsohn and Y. Elkana (Eds.), *Sciences and Cultures: Anthropological and Historical Studies of the Sciences*, Volume 5, pp. 1–76. Dordrecht: Reidel.

Elman, B. A. (1984). *From Philosophy to Philology: Intellectual and Social Aspects of Change in Late Imperial China*, Volume 110 of *Harvard East Asian Monographs*. Cambridge, MA: Harvard University Press.

Elman, B. A. (2005). *On Their Own Terms: Science in China, 1550–1900*. Cambridge, MA: Harvard University Press.

Engelfriet, P. M. (1998). *Euclid in China: The Genesis of the First Chinese Translation of Euclid's Elements Books I–VI [Jihe yuanben; Beijing, 1607] and Its Reception up to 1723*, Volume 40 of *Sinica Leidensia*. Leiden: Brill.

Gernet, J. (1985). *China and the Christian Impact: A Conflict of Cultures*. Cambridge: Cambridge University Press.

Graham, A. C. (1971). China, Europe, and the Origins of Modern Science: Needham's 'The Grand Titration'. *Asia Major* (16), 178–196.

Graham, A. C. (1978). *Later Mohist Logic, Ethics and Science*. Hong Kong: Chinese University Press.

Gua, S. (1997). *Mengxi bitan 夢溪筆談[Brush Talks from the Dream Brook]*. Yangzhou: Jiangsu Guangling guji keyinshe.

Guo, Z. (1993). *San zhi shi si shi ji Zhongguo de quan heng du liang*. Beijing: Zhongguo she hui ke xue chu ban she: Xin hua shu dian jing xiao.

Henderson, J. B. (1984). *The Development and Decline of Chinese Cosmology*. Neo-Confucian Studies. New York: Columbia University Press.

Henderson, J. B. (1986). Ch'ing Scholars' Views of Western Astronomy. *Harvard Journal of Asiatic Studies 46*(1), 121–148.

Huang, X. (2005). The Trading Zone Communication of Scientific Knowledge: An Examination of Jesuit Science in China (1582–1773). *Science in Context 18*(3), 393–427.

Hummel, A. (Ed.) (1943). *Eminent Chinese of the Ch'ing Period (1644–1912).* Washington, DC: US Government Printing Office.

Høyrup, J. (1989). Sub-Scientific Mathematics: Observations on a Pre-Modern Phenomenon. *History of Science 28*, 63–86.

Jami, C. (1994). Learning Mathematical Sciences During the Early and Mid-Ch'ing. In B. A. Elman and A. Woodside (Eds.), *Education and Society in Late Imperial China, 1600–1900*, Volume 19 of *Studies on China*, pp. 223–256. Berkeley, CA: University of California Press.

Jami, C. (1996). From Clavius to Pardies: The Geometry Transmitted to China by Jesuits (1607–1723). In F. Masini (Ed.), *Western Humanistic Culture Presented to China by Jesuit Missionaries (XVII–XVIII centuries)*, pp. 175–199. Rome: Institutum Historicum S.I.

Jami, C. (1999). 'European Science in China' or 'Western Learning'? Representations of Cross-Cultural Transmission, 1600–1800. *Science in Context 12*(3), 413–434.

Jami, C., P. M. Engelfriet, and G. Blue (Eds.) (2001). *Statecraft and Intellectual Renewal in Late Ming China: The Cross-Cultural Synthesis of Xu Guangqi (1562–1633)*, Volume 50 of *Sinica Leidensia*. Leiden: Brill.

Krayer, A. (1991). *Mathematik im Stundenplan der Jesuiten: die Vorlesung von Otto Cattenius an der Universität Mainz (1610–1611)*, Volume 15 of *Beiträge zur Geschichte der Universität Mainz*. Stuttgart: Steiner.

Kuo, S. (1997). *Pinselunterhaltungen am Traumbach: Das gesamte Wissen des alten China.* Munich: Diederichs.

Lackner, M., I. Amelung, and J. Kurtz (Eds.) (2001). *New Terms for New Ideas: Western Knowledge and Lexical Change in Late Imperial China*, Volume 52 of *Sinica Leidensia*. Leiden: Brill.

Lefèvre, W. (1978). *Naturtheorie und Produktionsweise: Probleme einer materialistischen Wissenschaftsgeschichtsschreibung—Eine Studie zur Genese der neuzeitlichen Naturwissenschaft.* Darmstadt: Luchterhand.

Martzloff, J.-C. (1980). La compréhension chinoise des méthodes démonstratives euclidiennes au cours du XVIIe siècle et au début du XVIIIe. In *Actes du IIe Colloqu International de Sinologie: Les rapports entre la Chine et l' Europe au temps des lumières*, pp. 125–143. Paris: Les Belles Lettres.

Martzloff, J.-C. (1997). *A History of Chinese Mathematics.* Berlin: Springer.

Needham, J. (1969). *The Grand Titration. Science and Society in East and West.* London: Allen and Unwin.

Needham, J. (1988). *Science and Civilization in China* (Reprint ed.), Volume 1–8 of *Science and Civilization in China.* Cambridge: Cambridge University Press.

Peterson, W. J. (1973). Western Natural Philosophy Published in Late Ming China. *Proceedings of the American Philosophical Society 117*(3), 295–322.

Porter, J. (1980). Bureaucracy and Science in Early Modern China: The Imperial Astronomical Bureau in the Ch'ing Period. *Journal of Oriental Studies 18*, 61–76.

Renn, J. and M. Schemmel (2000). *Waagen und Wissen in China: Bericht einer Forschungsreise.* Preprint 136. Berlin: Max Planck Institute for the History of Science.

Renn, J. and M. Schemmel (2006). Mechanics in the Mohist Canon and Its European Counterpart. In H. U. Vogel, C. Moll-Murata, and G. Xuan (Eds.), *Zhongguo ke ji dian ji yan jiu: di san jie Zhongguo ke ji dian ji guo ji hui yi lun wen ji, 2003.3.31–4.3, Deguo Tubingen*, pp. 24–31. Zhengzhou: Elephant Press (Da xiang chu ban she).

Schemmel, M. (in press). Stevin in Chinese: Aspects of the Transformation of Early Modern European Science in its Transfer to China. In H. Cook and S. Dupré (Eds.), *Translating Knowledge in the Early Modern Low Countries*, Volume 3 of *Low Countries Studies on the Circulation of Natural Knowledge.* Münster: LIT Verlag.

Schäfer, D. (2010). Technologie und Innovation im vormodernen China: Ein historischer Überblick. *Ferrum* (82), 15–24.

Sivin, N. (1973). Copernicus in China. In H. International Union of the and S. Philosophy of (Eds.), *Études sur l'audience de la théorie héliocentrique: Conférences du symposium de l'UIHPS, Toruń 1973*, Volume 6 of *Studia Copernicana*, pp. 63–122. Breslau: Zakład Narodowy Imienia Ossolińskich.

Sivin, N. (Ed.) (1977). *Science and Technology in East Asia.* New York: Science History Publications.

Sivin, N. (1982). Why the Scientific Revolution Did Not Take Place in China—or Didn't It? *Chinese Science* (5), 45–66.

Standeart, N. (1999). Jesuit Corporate Culture as Shaped by the Chinese. In J. W. O'Malley, G. A. Bailey, S. J. Harris, and T. F. Kennedy (Eds.), *The Jesuits: Cultures, Sciences, and the Arts, 1540–1773*, pp. 352–363. Toronto: University of Toronto Press.

Standeart, N. (Ed.) (2001). *Handbook of Christianity in China (Vol. 1: 635–1800).* Leiden: Brill.

Wardy, R. (2000). *Aristotle in China: Language, Categories and Translation*, Volume 2 of *Needham Research Institute Studies*. Cambridge: Cambridge University Press.

Wills, J. E. (1994). Brief Intersection: Changing Contexts and Prospects of the Chinese-Christian Encounter from Matteo Ricci to Ferdinant Verbiest. In J. W. Witek (Ed.), *Ferdinant Verbiest (1623–1688): Jesuit Missionary, Scientist, Engineer and Diplomat*, pp. 383–394. Nettetal: Steyler.

Wong, G. (1963). China's Opposition to Western Science During Late Ming and Early Ch'ing. *ISIS 54*(1), 29–49.

Yabuuti, K. (1997). Islamic Astronomy in China During the Yuan and Ming Dynasties. *Historia Scientiarum 7*(1), 11–43.

Yin, X. (2006). Influences of Western Military Technology and Mechanics on Chinese Ballistics. In J. Renn and B. Zhang (Eds.), *Transformation and Transmission: Chinese Mechanical Knowledge and the Jesuit Intervention*. Preprint 313. Berlin: Max Planck Institute for the History of Science.

Zhang, B., T. Miao, M. Schemmel, J. Renn, and P. Damerow (2008). *Chuanbo yu huitong: Qiqi tushuo yanjiu yu jiaozhu* 傳播与會通:奇器圖説研究与校注*[Transmission and Integration: 'Qiqi tushuo'—New Research and Annotated Edition]*. Nanjing: Jiangsu kexue jishu chubanshe.

Zou, D. (2006). The Concept of Force (li 力) in Early China. In B. Zhang and J. Renn (Eds.), *Transformation and Transmission: Chinese Mechanical Knowledge and the Jesuit Intervention*. Preprint 313. Berlin: Max Planck Institute for the History of Science.