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Craft Knowledge at the Interface of Written and Oral Cultures

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Abstract How did artisans in late imperial and Republican China reproduce technical knowledge, what role did writing play in knowledge reproduction, and to which extent did literate and oral knowledge cultures meet? This article looks at these questions from two angles: it reconstructs tacit, oral, and literate modes of knowledge transmission among artisans (in particular papermakers) in the nineteenth and twentieth century, and it looks at the production, circulation, and potential impact of texts dealing with artisanal techniques.

Keywords History of technology · China · Artisans · Paper making · Knowledge cultures · Tacit knowledge

Much recent work on early modern Europe has focused on the interface between the literate world of elite scholars and the tacit (though not necessarily illiterate) world of people who worked with their hands. As Pamela Smith has shown, artisans in early modern Flanders, Germany, and Holland were informed by an "artisanal epistemology" which prized works over words and knowledge gained from the manipulation of matter over textual learning and speculative thought (Smith 2004). Lissa Roberts and her collaborators demonstrate that much of what we now consider science owes its existence to the "mindful hand:" the close (albeit unequal) cooperation between non-elite technicians and elite philosophers (Roberts et al. 2007). Similar work remains to be done for China, where the study of technology is still too often the study of texts, with little consideration for how such texts reflected or informed actual practice. In the period, I am interested in here—Qing (1644-1911) and Republican period (1911-1949) China—artisanal practice was typically tacit. Most goods produced in China originated in small workshops or farm households that relied on experiential and embodied knowledge. Skills were transmitted directly

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from parent to child or from master to apprentice, often without being put into words, even less into writing. For many novices, training was part of their socialization into a kinship group or village, not a separate process of education. Yet, this was also a world in which competition forced producers to innovate or perish, and where merchants, local elites, and governments actively disseminated useful knowledge. In the more commercialized parts of China, a considerable percentage of the population enjoyed at least some degree of literacy. Even in less developed regions, most villages contained a few literate men who could explain written texts, and woodblock prints effectively conveyed information to those who could not read.[1] The fact that medical texts (gynecological treatises, in particular) were a main staple of commercial publishers, second in circulation only to school primers and cheap editions of the classics, shows that there were few obstacles to the downward transmission of complex and highly specialized knowledge—or, for that matter, to the upward transmission, through print, of popular cures and techniques (Brokaw 2007).

The same is true for agriculture: as Francesca Bray (2007) has shown, imperially sponsored agronomic science was closely integrated with farmers' local knowledge. While the great agronomic treatises of Jia Sixie, Wang Zhen, and Xu Guangqi (written in the sixth, fourteenth, and seventeenth century) were never widely read in the homes of farmers, they reached a stratum of literate landowners who adapted what they read to the local soil and climate, often drawing on the local knowledge of old farmers. Agronomic treatises were written in a way that facilitated this form of downward transmission: Xu Guangqi, for example, tested the accuracy and comprehensibility of his *Nongzheng Quanshu* by having carpenters reconstruct the tools depicted in his illustrations, and summarized techniques in the form of short rhymes that could be memorized by illiterate farmers.

As I will try to show, most forms of specialist knowledge showed much less integration between the written and the tacit and produced a far less extensive technical literature than agronomic science or medicine. To generalize over so wide a field is perilous, but the vast majority of "technical" writing before the twentieth century was produced by literati for a literati audience or by administrators for administrative use. Much of it took the form of textual exegesis, more concerned with the cataloging of written texts—the earlier and more arcane the better—than with providing practical advice for practitioners. Moreover, much of it never made it into print, or if it did, appeared in non-specialist collections that were unlikely to come to the attention of a prospective weaver, potter, or papermaker—or even to that of local merchant or administrators who might have introduced it to practitioners.

My aim here is not to belabor once again the well-known limitations of technical writing in China or to restate Joseph Needham's thesis of a widening gap between the knowledge of artisans and the literate culture of Confucian elites and administrators. Instead, I want to draw attention to the obvious but easily forgotten fact that much knowledge is conveyed without recourse to writing, and that in many situations writing is neither an efficient nor a reliable medium for knowledge reproduction. The point is not that Chinese artisans did not read or write: we know that artisans used written contracts, marked or inscribed their products, wrote lists

[1] Hayes (1985). For the role of illustrations in the circulation of technical knowledge, see Bray et al. (2007).

and charts to keep track of stores, and used ritual texts to pray for good fortune or thank deities and ancestors. Yet for the transmission of technical knowledge, they tended to rely on direct verbal or tacit instruction.

The problem with tacit knowledge cultures is of course that they leave few traces in the written record and are therefore difficult to document. There are however ways to work around this problem: archeologists and historians have learned to reconstruct the material practices and, to a lesser extent, the ideologies and epistemologies of artisans from the material record. They have also probed the institutions and vernacular cultures in which tacit knowledge production was embedded, using guild regulations, court records, or folk tales to reconstruct the life worlds of artisans.[2] In industries that have survived into the twentieth century, it is also possible to infer about earlier practices from fieldwork observations, although this needs to be done with caution. In the following pages, I reconstruct one such tacit knowledge culture, that of manual papermakers in Sichuan province. I draw on a variety of written sources, ranging from Qing period stele inscriptions to survey reports written by state administrators and industrial reformers in the mid-twentieth century, and on oral history interviews and fieldwork observations that I collected between 1993 and 2003.[3] In my description of training, information flows, workplace dynamics, and so on, I do to some extent extrapolate from these recent fieldwork observations. I believe that this is permissible because craft work is anchored in the human body and therefore subject to certain regularities: a sheet of paper can be molded only in a certain number of ways, and this to some extent delimits (though does not strictly determine) the ways in which work is organized and knowledge is reproduced. While papermaking takes up most of this discussion, my interest is in artisan's work in general and I will look at the wider literature on craft knowledge, literacy, and book culture in the concluding pages.

1 Tacit Knowledge in Practice: Papermaking in Jiajiang

Paper production in Jiajiang (located halfway between Chengdu and Leshan) is documented since the early Qing. In 1684, soon after the Qing conquest of Sichuan, Jiajiang papermakers were ordered to supply writing paper for the recently reestablished civil service examinations, an obligation that remained in force until 1905. In contrast to other paper industries in Sichuan (Liangping, Tongliang, and Guang'an) which produced coarse sacrificial paper, Jiajiang producers specialized in fine writing and printing paper. Its main markets were the Yangtze ports of Leshan, Yibin, Luzhou, and Chongqing, and the provincial capital of Chengdu, which developed a thriving print industry in the second half of the eighteenth century. In the late nineteenth and early twentieth century, Jiajiang paper was sold in all parts of the province and also in Yunnan, Guizhou, Gansu, and Shaanxi.[4] In the 1930s, an estimated 60,000—about one third of the county's population—derived their livelihood from papermaking or related trades. The industry reached its peak during

[2] Ulrich (2001); Smith (2004); Bray (1997).
[3] For a discussion of fieldwork and sources, see Eyferth (2009).
[4] Wang (1995); Cheng Quan undated manuscript, p. 48.

World War II, when the move of the national government to Chongqing boosted demand for paper. Papermaking was gradually phased out in the 1960s and 1970s, largely because communist grain policies forced the rural population, including rural artisans, to become self-sufficient farmers. It recovered in the 1980s; and by the early 1990s, Jiajiang had become one of the largest producers of handmade paper in China. The industry is still rural and household based; production is still largely manual, although most workshops now use diesel-powered pulp beaters. Historically, Jiajiang's main product was writing and printing paper of high to medium quality; today, most workshops produce so-called "Chinese art" (*guohua*) paper for brush painting and calligraphy.

Most people in the hills live in close-knit communities characterized by overlapping ties of common occupation, kinship, and shared residence. In Shiyan village, where I did most of my fieldwork, 80% of the population were surnamed Shi; in neighboring Zhangyan, Yangbian, and Macun, the Zhang, Yang, and Ma families dominated. As elsewhere in China, such single-surname groups were patrilocal and exogamous: sons stayed with their parents and inherited; daughters married out into neighboring communities. Such communities functioned as seemingly natural containers for the reproduction of technical knowledge. For people born in the paper districts, training was a function of growing up in a community where almost everybody shared the same skills. Most children were trained by their parents; in cases where the parents were not skilled, children were informally apprenticed to a relative or neighbor. As in most other Chinese crafts, training began at an early age and involved little explicit instruction; novices observed and imitated senior artisans; if they made mistakes, they were slapped or scolded.[5] Since recruitment was by birth, the community of skilled producers expanded at the slow rate of biological reproduction; there was therefore no need to limit the number of apprentices per workshop. Nor was there any need for explicit rules and regulations: existing hierarchies of gender, age, and generation were perfectly sufficient to regulate the flow of information in the community and to assign specific tasks to specific people.

Twentieth-century observers accused Jiajiang papermakers of excessive secrecy, but it seems that there were virtually no barriers to the circulation of skills and knowledge within these communities, and that the limited flow of information across communities arose from the nature of tacit knowledge rather than from willful obstruction. Concealment was impractical because paper workshops had no walls: they consisted of straw roofs on wooden pillars, open to view from all sides. It was also difficult because of the dense web of ties that linked household workshops to each other. Jiajiang paper workshops were generally small: although the biggest workshops in the Republican period operated up to eight paper vats and employed more than 100 workers, the typical workshop owned a single vat and used a mix of household and hired labor.[6] There was a constant mismatch between household size (4.9 in the 1940s, when such data become first available) and the fluctuating labor demands in papermaking. The basic unit of manual papermaking is the vat; to keep a vat in constant operation, a workshop needed five to six (ideally seven) permanent

[5] On the paucity of verbal instruction in Chinese apprenticeship, see Cooper (1980).
[6] For a detailed discussion of papermaking technology, see Eyferth (2009) and Pan (1979).

workers and a much larger number of short-term helpers during seasonal peaks. Workshops tried as much as possible to hire long-term workers, but in a situation in which skills were widespread and entry costs were low, skilled persons usually preferred opening their own shops to hiring out. Moreover, labor demand in the workshops fluctuated heavily, due to seasonal variations and to the ups and downs of markets rendered volatile by frequent wars, blockades, famines, and inflation. Workshops dealt with such fluctuations by borrowing labor and equipment from neighbors who had excess capacities, and returning their debt whenever they could.

Labor exchange took two forms, formal and informal. Informal labor exchange consisted in a simple "helping out" (*bangmang*) between neighbors: men might lend a hand to help move heavy goods or shift equipment; women joined their neighbors in such time-consuming tasks as picking knotty bits out of the pulp. Workshops also lent tools, cash, and raw materials to each other; shared soaking basins, steamers, and drying walls; and exchanged market information. These informal exchanges created a constant traffic between workshops, and as people, tools, and goods moved back and forth between workshops, information followed. Formal labor exchange took place mainly in the steaming season, when the soaked and half-fermented bamboo was steamed in large wooden casks or steamers. These steamers were typically shared by groups of households, which used them in turn and pooled their labor during the days of most intensive work.[7] Steaming required a labor input of about 180 workdays in the space of just five days. In order to recruit this much labor, workshops invited all their neighbors for a few days of hard and boisterous communal work. No wages were paid, but all helpers took part in a daily banquet and workdays were recorded and eventually returned. Labor exchange around the steamer created stable groups of cooperating workshops and facilitating information flows.

Workshops owners I interviewed sometimes claimed that they or their ancestors owned secret recipes which they did not share with outsiders, but such claims cannot be taken at face value. Recipes in a strict sense did not exist—could not exist—because raw materials in the workshops were so bulky that they were difficult to weigh or measure, and so uneven in their quality that exact measurement would have been of little use. Rather than following fixed recipes, papermakers responded flexibly to changes that occurred in the production process: if their bamboo was harvested late and was therefore brittle and short-fibered, they added tree bast fibers to give the paper greater strength; if the summer heat caused the pulp to rot and curdle, they added extra mucilage to reduce clotting. What distinguished the master from the less experienced papermaker was not some secret formula but the capacity to harness biological processes that were never entirely predictable and to produce paper of constant quality from changeable raw materials. This is not to say that papermakers never tried to claim technologies as their individual property; only that such claims rarely succeeded. Old papermakers recall, for example, that the first man who obtained chlorine bleach from a Chongqing merchant used it only by night and then only in a closed storage shed; when his neighbors asked him how he bleached his paper so quickly and effectively, he said that he had learned a magic spell that

[7] Some steamers were jointly owned but most belonged to big workshops. Since steamers rot if not used, it was in the owners' interest to let them out for a fee or for free.

transformed the paper overnight. However, he was soon found out and the use of bleach became common throughout the paper district. Other innovations—the use of sulfur smoke for bleaching, of alum and plant glues for sizing, starch and gypsum for loading, etc.—also spread quickly.

Cooperation and knowledge sharing between workshops was facilitated by a kinship ideology that emphasized the equality and to some extent exchangeability of male agnates belonging to the same generation. The key here was *beifen* or "distinction between generations:" the practice, common in all parts of China, of marking members of the same generation with a shared character (e.g., Shi Weiling, Shi Weibo, etc. for the sons of the Shis' founding ancestors; Shi Keshan, Shi Kefu, etc. for the generation of their grandsons, etc.) and of treating generational seniors with the deference due to parents or grandparents. Before 1949, generational juniors among the Shis were supposed to stand up when elders entered the room, sit at different tables during meals, speak to seniors only when addressed, and use respectful terms of address; and a lineage council enforced these rules and punished offenders during a yearly gathering on Qingming day. Despite these harshly hierarchical overtones, *beifen* was less about generational inequality than about the equality of men belonging to the same generation, expressed in terms of address that erased the difference between brothers and distant cousins and in the common practice of agnatic adoption (*guoji*), in which an heirless man requested a "surplus" son from a same-generation lineage cousin and raised him as an heir.[8] Rituals at ancestral graves, the siting of graves, and forms of ancestral worship all emphasized horizontal generational status and downplayed vertical descent, thus discouraging the formation of individual descent lines that might have monopolized technical knowledge to the exclusion of other lines.

This horizontal and inclusive version of Chinese kinship was reinforced by the construction of craft knowledge as a gift from the ancestors, who had established the craft for the benefit of all descendants rather than for a single individual or lineage branch. This is expressed most clearly in a recent stele, commissioned by the Shis in 1993 to record a new list of twenty generation names, to be used when the present one (laid down in 1667) will expire. The text recounts how the first ancestors settled down in Jiajiang, established "the art of papermaking," and transmitted "the standards of loyalty, filial piety, propriety, and righteousness" to their descendants. It enjoins the Shis to thank the ancestors for their gift and to transmit their teachings to future generations. This construction of "the art of papermaking" as the inheritance of all Shis did not give individual Shis the right to a full and equal share in the common stock of knowledge, but it seems to have given them access to basic training and employment and perhaps to assistance from wealthier members in times of need. At a time when wage workers in many parts of China "faced the dreaded prospect of the extinction of the family line," even poor members of papermaking communities earned enough to marry and form families.[9] For Jiajiang papermakers, as for artisans and protoindustrial producers in early modern Europe, the "property

[8] On *guoji*, see Cohen (2005).
[9] Huang (1985), p. 310.

of skill" was primarily a form of membership in a community that regulated their work and guaranteed their livelihood.[10]

1.1 Innovation and Diffusion of Techniques in the Paper Industry

Early Chinese paper was made from hemp, straw, and tree bark; bamboo, while plentiful, was not used because of its high silica content. Bamboo paper is first mentioned in the Tang dynasty (618-907); it became common in the Song (960-1207) but remained associated with the southeastern provinces of Fujian and Zhejiang, where papermakers had learned to break down the tough fibers by steaming the bamboo first with quicklime and then with soda ash. It was only in the Ming and Qing that the new technology spread beyond the southeast (Dai 1994; Pan 1979), carried by successive waves of migrants from Fujian and Jiangxi to Guangdong, Hunan, Hubei, and Sichuan.[11] "Shed people" (*pengmin*)—named after the reed shacks in which they lived—practiced swidden agriculture and engaged in extractive industries and the cultivation of indigo, tobacco, and ramie for the market. Next to logging, charcoal burning, and cash crop cultivation, papermaking was one of the mainstays of the *pengmin* economy, and it is likely that these very mobile groups introduced (or reintroduced) papermaking technology to Sichuan when the province was repopulated after the devastations of the Ming-Qing transition.[12] Just as migrants from Jiangxi and Hunan had brought papermaking skills to Sichuan, Sichuanese migrants carried their skills to areas further west in Yunnan, Guizhou, and Shaanxi.[13] In the nineteenth century, the mountains of southern Shaanxi absorbed large numbers of migrants from Sichuan, and many of the paper workshops in this remote area were staffed by workers from Sichuan.

Republican period sources deplored the "stubborn secrecy" of Jiajiang papermakers, claiming that workshop owners "passed their secrets from father to son for ten or 20 generations" and refused to share them even with close friends (Sichuan Jingji Yuekan 1935). It is true that papermakers resented and occasionally resisted pressures from an intrusive government that asked them to provide full workshop access to urban observers—demands that from the point of view of papermakers fell little short of industrial espionage. Yet the fact that the same observers wrote detailed technical descriptions of the industry, based on information provided by workshop owners, belies the claim of excessive secrecy. In fact, in most situations there was no need for secrecy: the remote location of the paper districts kept most visitors away, and short-term guests presented no problem because craft skills, as papermakers knew well enough, could not be learned by simple observation.

Communities imposed no restrictions on the movements of their members, and skilled workers—men and women—who wished to find employment or set up shop

[10] For the "property of skill" among European artisans, see Somers (1996).

[11] Wang, J. (2006). Not only are bamboo paper technologies across China similar, but there is also much overlap in the terminology for equipment, work processes, and paper types.

[12] *Pengmin* settlers are discussed in Vermeer (1991), and Averill (1983).

[13] A transfer of papermaking skills from Sichuan to Yunnan is mentioned in Fei Hsiao-t'ung [Fei Xiaotong] and Chang Chih-i [Zhang Zhiyi] (1945). Cynthia Brokaw (2005) describes a similar process in the case of the Yuechi (Sichuan) woodblock carvers, originally from Jiangxi, who carried their craft to Guangxi and Yunnan.

outside Jiajiang were always free to do so. Papermakers from the Hedong ("east of the river") paper district were known to make paper of the highest quality, and workshops in Hexi ("west of the river") and in neighboring counties recruited their workers from there. Paper workshops in Dazhu, Liangping, and other counties in eastern Sichuan also recruited Jiajiang experts (Sichuan Yuebao 1935). If the superior techniques used in Jiajiang did not spread very far, this was because the market for fine writing and printing paper was smaller than that for the cheap, coarse sacrificial paper produced elsewhere in Sichuan.

Next to migration, trade networks were the most important medium for the diffusion of technology. Sichuan's paper market was highly fragmented, with different types of paper sold in different localities. Chongqing's paper shops, for example, bought large-format *lianshi* and *laolian* paper; traders in Chengdu preferred bleached *duifang*; those in Kunming bought large *gongchuan*, etc. Some products sold only in one or two counties: the only market for five-colored *pingsong* was the small town of Qiongzhou; "foreign small blue" (*yangxiaoqing*) sold only in Ziyang and Neijiang. Market demand changed rapidly throughout the late Qing and Republican eras as improved transportation opened new markets in Yunnan, Shaanxi, and Shanxi, each of them with its own idiosyncratic patterns of demand, and the introduction of lithographic and letterpress printing created new markets for western-style printing paper. As paper traders introduced sulfur, chlorine bleach, and soda ash, workshops quickly mastered these new techniques and passed them on to friends and neighbors. Today, and presumably also in the past, skilful papermakers are also able to "reverse engineer" paper, i.e., to analyze a sheet of paper purchased on the market and produce virtually identical copies. They do this by feeling the glossy or matte surface of the paper, tearing it to examine the fibers, touching it with a wet finger or a brush to see how water is absorbed, etc. These skills allowed Jiajiang papermakers to quickly learn to make different types of western-style printing paper: no mean feat, since lithographic and letterpress printing, with their fast movement and oil-based ink, make different demands on paper than traditional woodblock printing.

A good example for this process of adaptation and innovation comes from the workshop of Shi Ziqing (1894-1938), Jiajiang's most famous papermaker. Ziqing had learned early on to make "imitation *xuan*" (*fangxuan*) paper, similar in quality and format to the famous *xuan* paper from Anhui. When World War II broke out, patriotic Chinese artists such as Xu Beihong, Zhang Daqian, and Qi Baishi fled to Sichuan and Yunnan. After the fall of Anhui to Japanese armies, they found themselves cut off from their paper supplies and turned to Jiajiang. In 1942, Zhang Daqian (who as a Sichuan native was familiar with Jiajiang paper) teamed up with Shi Ziqing's son Shi Guoliang. For two weeks, Zhang and Shi spent their days in the workshop (and their nights, according to old people in Jiajiang, drinking and smoking opium), experimenting with different raw materials. In the end, they came up with a type of paper that was strong enough to withstand Zhang's powerful brushstrokes. While Guoliang gained prestige and perhaps a larger market share from his association with the famous painter, he did not come to "own" the new formula as a proprietary technology. Other producers in and outside Shiyan village soon learned to make similar paper, and the new paper (known as *Daqian zhi*) became the standard for good painting paper.

1.2 Writing in the Paper Workshops

Jiajiang papermakers lived in a world that was saturated with writing. In 1937, Jiajiang had 117 primary schools—about one per village—as well as a large number of private schools (*sishu*). Men born in the 1930s typically had two to four years of *sishu* schooling; only the very poor received no education.[14] Like other paper districts, Jiajiang developed its own printing industry. The county's earliest print shop, the Juyuantang, opened in the 1790s, at the same time when the arrival of qualified printers from Jiangxi gave a boost to the Chengdu book industry. It remained in operation until the 1910s, selling school primers, the Four Books of Confucian learning, historical works, and collections of Tang poems. Other shops printed popular novels, opera libretti, folk songs, and collections of popular stories and folk tales.[15] In the Republican period, 20 workshops produced colored New Year pictures (*nianhua*) and calendars, which were exported to places as far as Guizhou and Yunnan (Wang 1989). Modern lithographic printing was introduced in 1933; and by 1949, Jiajiang had ten mechanized print shops which produced advertisements for companies in Chengdu, Yibin, and Jianyang.

It is difficult to know what kind of printed goods circulated among papermakers: little survives, perhaps because paper products were immediately returned to the vat when they were no longer needed. At the very least, most homes would have been decorated with *duilian* scrolls and a *jiashen* poster—a red paper sheet, pasted above the family altar, which served as the spirit seat of the ancestors and the household gods. One would also expect that some of the almanacs, school primers, and poetry collections produced in Jiajiang found their way into the paper districts. Below, I list some of the ways in which writing may have been used in paper workshops.

Lists and Ledgers Record keeping is one of the earliest and most common functions of writing, widespread even in contexts of limited literacy.[16] Some of the workshop owners I interviewed in the 1990s recorded their income and expenses, but most did not and saw no need to do so. In large workshops where workers were paid piece rate wages, both workers and employers needed to keep track of output. Vatmen recorded their daily work by using a simplified abacus (consisting of two rows of five beads each) that was attached to the vat (Sheng and Yuan 1995). Since workers' accounts were settled only once a year, on the last day of the lunar year, employers needed to record their workers' output, as well as cash advances and deductions for shoddy work or broken tools. It is not clear how they did this, though old workers remembered that in Shi Ziqing's workshop, work tasks were recorded by his wife, who was illiterate. Perhaps she used a simple notation system, such as drawing one stroke of the character *zheng* for each completed task, so that each completed character stands for five completed tasks.

Marks and Brands High quality writing paper was a brand name product, stamped by the paper merchant or the producer, who thereby vouched for its quality. The most common practice was for the merchant to stamp his seal on the edge of a ream

[14] Interviews in 1995-1996.
[15] Ren (no date), p. 3; Wang (1991).
[16] See, for example, Goody (1987).

of paper. Western papermakers created watermarks by soldering wires to their paper molds, which left an imprint on the sheet. Chinese molding screen are flexible, which makes it difficult to attach watermarks, but when Shi Guoliang made paper for Zhang Daqian, he had Zhang's name and a cloud pattern embroidered on the screens in tiny glass beads. The fact that paper was marked with a workshop name did not necessarily mean that it was produced in the workshop: some large shops sold paper produced by their relatives and neighbors under their own name.

Contracts In contrast to the sale or lease of land and buildings, most commercial transactions in the paper industry were done without written contracts. Small merchants usually paid cash and therefore had no need for contracts. Sales by big workshops to big merchants, by contrast, involved open accounts that were settled once a year. In the initial stages of a trading relationship, sellers and buyers might use simple contracts, but once a relationship of mutual trust existed, contracts were no longer used. Labor contracts were always oral; other transactions (cash loans between neighbors, lease or sharing of equipment) were also done without recourse to writing.

Popular Religion The one aspect of papermakers' lives in which the written word was central was religious ritual: requesting divine help, thanking deities for received favors, or worshipping one's ancestors invariably involved the use of inscribed paper or of texts and charms produced by religious specialists. As Francesca Bray has argued, a cultural history of technology needs to consider rituals and domestic architecture as part of the wider sociotechnical system (Bray 1998). In Jiajiang, lists of generation names inscribed on tombstones, stelae instructing papermakers on how to worship Cai Lun (the deified inventor of paper and protector of the trade), and *jiashen* scrolls listing the household's ancestors and protective deities all helped to structure social relations and reproduce technical knowledge. Even though these are not technical writings in the strict sense, they must be seen as part of papermaking technology.

Like the printers of Yuechi in Sichuan, who carved woodblock prints but were often illiterate, papermakers in Jiajiang produced the material means for a written culture in which they did not fully participate. A man like Shi Ziqing enjoyed extraordinary prestige: he socialized with literati painters, was treated with great respect by county magistrates, and was twice awarded honorary plaques by the provincial government. However, he "had little education and could barely read and write" (*wenhua bu gao, cu shi wenzi*; Yang 1986). Formal learning was not essential to his success, and although he sent his eldest son to Chongqing to study modern papermaking, it was his workshop-trained second son who succeeded him after his death.

1.3 Writing About Paper Production

What written information was potentially available to papermakers and how accessible was it? We do not know, of course, what texts existed locally, in gazetteers, *biji* ("brush notes"), or manuscripts that have not yet been studied. However, paper historians in China and elsewhere have combed through much of the extant literature and produced convenient overviews of the main Ming and Qing sources on papermaking (Wang 2006; Pan 1979; Tsien 1985). The most important of

these sources is Song Yingxing's *Exploration of the Works of Nature (Tiangong kaiwu*, 1637*)*, which contains a detailed discussion of papermaking techniques based on careful observation and accompanied by illustrations. The book's fame as the greatest work on Chinese technology before the twentieth century contrasts with its very limited circulation: it remained in print only for a short time during the tumultuous years of the Ming-Qing transition and then disappeared from China, though it remained in print in Japan. Large parts of the text were incorporated into the *Gujin tushu jicheng*, but the enormous size and limited circulation of this encyclopedia (10,000 *juan*; only 64 official copies were printed before the 1860s) put it out of reach of all but the most privileged users (Schäfer 2005).

In addition to the *Tiangong kaiwu*, paper historian Pan Jixing lists three late Qing texts that offer authoritative descriptions of handicraft papermaking. Yang Zhongxi's *Snow Bridge Poetry Talks* (*Xueqiao shihua*) incorporates a one-page description of the procedure to make bamboo paper, recorded by Huang Xingsan in Zhejiang in 1849. This is a detailed, accurate first-hand account, but it remained unpublished until 1913; when it appeared in print, it was in a volume of essays penned by a reclusive Qing bannerman—a fact that must have limited its impact.[17] The situation is similar for Hu Yueyun's much longer and more detailed "On Paper" (*Zhi shuo*), described by Pan as "the most comprehensive work on papermaking since [the tenth century]."[18] Only the last three pages of this 30-page text are based on firsthand observation, describing the making of *xuan* paper in Hu's native Jingxian, Anhui. The *Zhi shuo*, too, did not see publication until the Republican period, and appeared in a privately published collection of philosophical and literary essays, intended for a small audience of fellow literati.[19] A third important text listed by Pan is Liu Yueyun's encyclopedic *Chinese Methods for the Investigation of Things* (*Gewu Zhongfa,* completed 1871), which includes a compilation of sources on papermaking. While clearly intended for a large audience, "the carving of the text was apparently never completed, nor were there any later editions, so that the number of transmitted copies is extremely small."[20]

To sum up, four of the five most comprehensive discussions of handicraft papermaking technology produced before the twentieth century were almost certainly inaccessible not only to practicing papermakers but also to local administrators, merchants, or literati who might have introduced them to such knowledge. The *Tiangong Kaiwu* had a very limited circulation until its rediscovery in 1907; the other texts were written in the last decades of the Qing and appeared in print only after the end of the dynasty, in minor publications intended for local literati audiences. Add to this the extreme jealousy with which many book owners guarded their books, and it seems improbable that information from these texts could have trickled down to practitioners (McDermott 2006).

Only one of the texts listed by Pan was accurate and accessible enough to have served as a potential conduit for practical knowledge. This was Yan Ruyi's 1822

[17] The text is reproduced in Deng (1974). Tsien (1985), pp. 71-72, has an English translation.
[18] Pan (1979), pp. 219-20.
[19] Hu Yunyu [Hu Pu'an], *Puxuezhai congkan* (Collected Writings from the Studio of Studying Simplicity), Shanghai 1923, *ce* 3.
[20] Pan (1979), p. 219. Modern editions are based on a single extent copy printed in 1900. See Liu 1996.

Sansheng bianfang beilan (An Overview of Border Defense in Three Provinces). Here is a short excerpt, describing the steaming of bamboo in the Shaanxi-Sichuan-Hubei border area:

> They make a separate lime pond, mixing quicklime [into the water] to create a lime solution. The bundled bamboo is then piled up in the pond so that it can be completely soaked. It is first being dipped in the solution, then crushed and piled up in layers as one would build a wall. After ten days, the lime solution has permeated the bamboo. After removing the ropes [that held the bundles together], the bamboo is brought to the steamer. Steamers have wooden walls which are bound tightly together with bamboo ropes. The width is nine *chi* at the base and seven *chi* at the top; height is one *zhang*. Each steamer has a capacity of six to seven hundred bundles. The first steaming lasts four to five days and nights. Next to the steamers there are ponds with an inlet and an outlet, so that fresh water can flow through. After steaming, the fibers are rinsed in water for three days until the lime is washed away. The bamboo then resembles flax fibers. They are then packed back into the steamer to be steamed with wood ash lye.[21]

This is a very precise description of a crucial part of bamboo paper technology, written in clear, simple prose. The work in which it is included belongs to the tradition of late Qing statecraft writing. Its author Yan Ruyi was a nationally prominent administrator and frontier defense specialist, whose *Sansheng bianfang beilan* was compiled at the request of the imperial court and widely read by other statecraft scholars. Yan wrote it while trying to restore social order in the volatile Shaanxi-Sichuan-Hubei borderland after the White Lotus rebellion (McMahon 2002; McMahon 2009). He and his associates were actively involved in the propagation of knowledge related to farming and sericulture—activities which for Qing officials had moral significance beyond their economic use—and even wrote poems and speeches in vernacular language to promote such knowledge. Yan wrote long descriptive poems about paper workshops, timber camps, and iron foundries, in which he expressed admiration for the ingenuity and hard work of their *pengmin* workers. In contrast to some of his other works, these poems were not intended for didactic use.[22] Nonetheless, if we are looking for a text that might have bridged the gap between oral and written cultures, the *Sansheng bianfang beilan* is one of very few plausible candidates.

In general, sources produced by administrators for administrative purposes were more likely to reach practitioners than specialist treatises written by and for literati. Local gazetteers (*fangzhi*) in paper-producing areas often included brief descriptions of these industries, some of which contain technical information.[23] However, the emphasis is often more on the hard work of the papermakers and on the moral values that such work inculcates. The following excerpt from the Jiajiang county gazetteer is typical:

[21] Wang (2006), p. 320.

[22] Yan Ruyi, *Sansheng bianfang beilan* (An Overview of Border Defense in Three Provinces), *juan* 17, pp. 64b-66b. The poems omit much technical information and are in literary Chinese. For examples of didactic texts see *Sansheng bianfang beilan*, *juan* 18 *shang*, pp. 37a-39b, 40b-44b, *juan* 18 *xia*, pp. 22b-24b, 69b.

[23] For excerpts from gazetteers, see Wang (2006), pp. 318-19; Pan (1979), pp. 109-13; Dai (1994), pp. 196-201, 213-18.

> No work is harder than that of papermaking families, and none consists of more different processes. [The old gazetteer] states that "men till and women weave; they work harder than people in other counties." Papermaking surpasses even plowing and weaving: farmers rest between sowing and reaping, workers toil all day but rest at night. Only the families of papermakers work spring and summer, day and night. Old and young, men and women, are all employed in their respective tasks.[24]

If technology is described, it is sometimes abridged in almost comical fashion. This is how an 1836 stele text in the Jiajiang hills describes the papermaking process: "In our county, bamboo is valued for making paper. Cut the stalks, remove the green, soak with lime, steam with fire, rinse with water, pulp with mortar, mold with screen, brush on wall: this is the way to make paper."[25] The ruling assumption in most of the texts discussed in this section is that it is neither necessary nor possible to fully reproduce practical knowledge in written texts. Huang Xingsan's 1849 report on papermaking in Zhejiang sums this up: "As for choosing the best raw materials, differentiating between the pure and the mixed, recruiting and managing workers, only those who have grown old in the trade understand this; words cannot exhaustively express these matters."[26]

1.4 Written and Oral Knowledge in Other Craft Industries

A comprehensive overview of the intersection of written and oral knowledge cultures in all Chinese handicraft industries is impossible here, but a few observations are in order. Firstly, *Verschriftlichung*—the translation of oral knowledge into written text—was uneven across industries. Industries that were of central interest to the state or to literate elites were more likely to be written about than those producing humble and quotidian products. Agriculture and sericulture (*nongsang*), hydraulics, and textile production were described in great detail, though even the most detailed descriptions could be mute about technology. For example, the need to manage and control the large number of government-employed artisans (12,000 in palace workshops, 14,000 in provincial manufactories; Moll-Murata 2005) led to the production of numerous handicraft regulations (*jiangzuo zeli*), but since Qing officials left the details of production to foremen and master craftsmen, these texts are largely silent about how things were produced (Moll-Murata and Vogel 2005). A similar point can be made about elite collectors. Many elite men cared passionately about inkstones, carved jades, musical instruments, and other luxury objects about which they wrote in poems or extended treatises (*zhi*, *pu*). However, the fact that connoisseurs confidently praised, criticized, and instructed the artisans who produced such objects does not mean that they understood (or much cared about) how they were made.[27] This was largely a literature of appreciation, concerned with textual lore and with the resonance between the refined person and the objects that surrounded him or her. Detailed instructions on how to make (rather

[24] Liu (1985), p. 31.
[25] Gufosi stele. Transcript in the possession of the author.
[26] Deng (1974), p. 207.
[27] On connoisseurship, see Clunas (1997). On artisans and their patrons, see Dorothy Ko's unpublished work on female inkstone carvers and embroiderers.

than interpret and appreciate) things were perhaps most common in the case of feminine crafts: silk embroidery, for example, was extensively discussed in illustrated manuals (Fong 2004).

Secondly, not all technologies lend themselves equally well to textual or graphic representation. Graphics are powerful tools for the representation of machines, but mechanical engineering played a less central role in China than it did in Europe. Many of the most sophisticated Chinese technologies were thermal and biochemical, concerned with the control of heat (metallurgy, ceramics), steam (papermaking), evaporation (salt, sugar), oxidation (tea, lacquer), and fermentation (indigo dyes, alcohol, foodstuffs) (Daniels 1996). Before the advent of thermometers and other measuring techniques, such technologies relied largely on the artisans' trained senses, a form of knowledge that was not easily reproduced graphically or in writing. Even industries with a large mechanical component were heavily dependent on tacit knowledge. For example, the derricks, drills, and evaporation pans of the Sichuan salt industry could be described in texts and graphics, but the success of a salt well depended on the bodily skills of highly specialized artisans: prospectors who knew to "select a well site by the smell of the grass and soil in the area," or furnace operators who knew how to gage and regulate the heat at different stages of the evaporation process.[28] The situation seems to have been similar in mining and iron smelting, both of which relied heavily on tacit knowledge and remained poorly documented until the nineteenth century.[29]

Thirdly, what we know about printing, book culture, and reading habits suggests that technical writings did not circulate widely at the village level. The Ming and Qing print industries surveyed by Cynthia Brokaw produced almanacs and handbooks in great quantity and at low prices, but the information contained in them was of a social or religious nature. Research on popular reading habits, admittedly from the twentieth century, show that genealogies, handbooks of family and social practice, almanacs, collections of *duilian* couplets, educational texts, guides to letter writing, encyclopedias for daily use, poetry, and novels were the most common printed materials at the village level (Hayes 1985). Popular educational texts such as the *Youxue Qionglin* contained sections on inventions (*zhizuo*) and skills (*jiyi*), which introduced the vernacular and literary names of common products and listed their mythical or historical inventors. Such texts taught commoners how to use polite speech and classical allusions but did not aim to convey technical information. The one exception is the *Lu Ban Jing*, a carpenters' manual that circulated widely and was quoted extensively in popular almanacs. However, "it is unlikely that *Lu Ban Jing* was ever used to any extent as a reference book by carpenters and joiners. These craftsmen learned their trade while working with a master, and certainly not from a book."[30] The text was primarily a guide to ritual and building magic, used by carpenters to bring blessing or misfortune on a house and by house owners to counter carpenters' charms.

[28] Zelin (2005), pp. 14-21, 125-31.

[29] For a discussion of sources, see Wagner (2009), Golas (1999). Wagner's discussion of traditional iron production in the twentieth century makes it clear that these industries relied on tacit knowledge.

[30] Ruitenbeek (1993), p. 145.

So far, I have not considered the possibility that technical knowledge circulated in manuscript form. Cynthia Brokaw reminds us that Chinese reading culture in the late imperial period remained very much a manuscript culture. Manuscripts were widely used for the transmission of family medical techniques and other knowledge that was to be transmitted to insiders but concealed from outsiders (Brokaw 2005). What we know from the medical tradition suggests that manuscripts were not meant to be self-evident, transparent texts; their meaning needed to be explained by a teacher, and students often had to "appropriate" the texts through recitation and hand copying (Hsu 1999). The relationship between tacit knowledge and writing is nicely captured by anthropologist Mu Peng in her work on ritual masters in Hunan. These specialists (who describe their work as "doing handicraft," *zuo shouyi*) use secret texts in the form of manuscripts or annotated books, which they show only to trusted disciples. However, as they point out, mere texts are of no use: in order to become useful, knowledge had to "pass through mouths of flesh" (*guo roukou*), i.e., to be explained and contextualized by a teacher Peng (2010).

At this point, it may be useful to pause and consider what writing can and cannot do. Writing in itself cannot encode an entire technique in such a way that it may be decoded by people who have no previous knowledge of it. If we sometimes believe that it can, it is because we are not fully conscious of the extent of our tacit knowledge and its contribution to the decoding of the written text. It is also because industrial societies provide the standardized conditions under which technoscientific writing appears to be self-explanatory and true. Explicit technical instructions "work" because so much of our technical environment is standardized: a recipe for a cake, for example, can be made sense of by a person with little tacit skill only because flour and sugar are industrially manufactured and thus of uniform quality, ovens are equipped with thermometers, author and reader use standardized systems of measurement, etc. (Shapin 1995; O'Connell 1993). In the absence of far-reaching standardization, the power of writing is far more limited. Writing worked best for technologies that were easily encoded and decoded: information on tools and machines, for example, traveled well because it can be represented graphically and because every market town had a carpenter who knew how to decode it. However, technology cannot be reduced to machines and tools. All technologies have tacit components which defy graphic representation. Secondly, writing could transfer knowledge from one group of practitioners to another group of similarly skilled practitioners—say, from papermakers in Anhui to papermakers in Sichuan. In order for this to work, it had to be specific: generic descriptions of papermaking or silk reeling are of no use to the artisan who already knows the craft. This combination of specialized content and super-regional reach was rare in Chinese technical writing before the twentieth century: descriptions of specific techniques were often written for a local audience, as was the case with Hu Yueyun's *Zhi shuo* and Huang Xingsan's *Zaozhi shuo*, while texts that aimed to reach a wider audience, such as the *Tiangong Kaiwu*, tended to describe generic techniques. Thirdly, texts could inform educated readers—merchants, local gentry, or officials—about the existence of certain techniques, their potential advantages and risks, their degree of difficulty, the necessary skills and raw materials, etc. The readers could then recruit skilled specialists to reconstruct these techniques through a process of trial-and-error

experimentation.[31] Texts in this case do not serve as self-contained carriers of information; instead, they provide "a set of landmarks along the way, a means of checking that [the learning process is] still on track."[32] In addition to these functions, texts could of course enlighten their readers in a general way, without expecting them in any way to put this knowledge into practice.

From the perspective of the artisan, texts served rather different functions. Texts, especially printed texts, were cherished as a source of authority—not only by the literate but also by illiterate users who may have ascribed some sacred quality to the written word. Klaas Ruitenbeek speculates that the *Lu Ban Jing* was "treasured at least as much by a carpenter who could not read as by a colleague who could," because it embodied the entire wisdom of the trade.[33] Texts were also used to support the transmission of knowledge that nonetheless remained primarily oral, along the lines suggested by Peng Mu. Finally, texts were used as memory aids to help with complicated tasks. Caroline Bodolec reports that masons on eighteenth century building sites used notebooks containing abridged formulas for the calculation of vaults, derived from the official building manual *Gongcheng zuofa*.[34] Artisans, in short, were likely to use texts in local ways, as private stores of information or teaching aids, often in manuscript and usually in conjunction with tacit and oral knowledge.

1.5 Technical Writing and Control

If historians give great importance to technical writing, it is because they expect such texts to be transformative: accurate technical descriptions give readers a vantage point from which they may contemplate and eventually carry out the transformation of the workplace. This was the explicit program of Diderot's *Encyclopédie*, which aimed to open up the "blind" practice of the workshop to the eye of the rational philosopher—to remove, in Cynthia Koepp's words, "the inefficient and inarticulate world of work from the hands and mouths of the workers and to place it in printed form before the eyes of an enlightened 'management' whose ordered purposes it would serve" (Koepp 1986; Sewell 1986). It seems to me that this transformational intent is absent from most Chinese technical writing before the twentieth century. Not that the intent to subordinate the world of work to an "enlightened management" was absent, but this subordination did not necessarily take the path of concentrating technical competence in the hands of merchants or officials. Consider this quotation from Fan Tong's *Cloth Classic* (*Bujing*), compiled in 1751, exactly the same year as the first volumes of the *Encyclopédie*:

> The business of purchasing cloth has its own way (*dao*). [The buyer] sits upright and straightens his facial expression, purifies his mind and stills his

[31] See Golas (2007), p. 587, for a hypothetical example of how this might have worked.

[32] See Tim Ingold's amusing and enlightening discussion of the frustrations involved in learning how to make knots solely from written instructions and diagrams. Ingold (2000), pp. 357-58.

[33] Ruitenbeek (1993), p. 145.

[34] Bodolec (2005) argues that calculations used by masons in contemporary Shaanxi can be traced back to Qing building regulations, indicating a trickle-down effect from official texts to popular practice.

> thoughts. He … needs to know that his spirit is most alert in the morning hours; he avoids working in the afternoon, when his eyes are dim and dazed. [He pays attention] to the light and shadow in the place where he examines the cloth and knows that things alter their appearance when he changes his position. … He shuns sudden stillness and sudden movement; he avoids sudden light and sudden darkness. … To clearly distinguish [cloth by] provenance, to securely identify [types of] yarn, never exceeding, never falling short—this is the true Path of the Mean. … When you show a student one quarter and he cannot guess the other three, don't teach him anymore. A carpenter can teach [his apprentice] the correct measurements but can't make him skilled; he needs to understand intuitively.[35]

Despite the Daoist-inflected language, Fan Tong's advice is eminently practical—more practical, in many ways, than the *encyclopédistes*' utopian project of translating the knowledge of all crafts and trades into precise scientific language. Most of the *Bujing* text describes the look, touch, weight, yarn count, and production techniques of different types of cloth produced in the Songjiang cotton districts, interspersed with advice to purchasing agents (known as "cloth-watching friends," *kan bu pengyou*) on how to slant their head when looking at the weave, to weigh the cloth in the hand, or to recognize and remember the feel of different types of cloth. Qiu Pengsheng (2009) is certainly right when he sees the *Bujing* and similar manuals as crucial moments in the appropriation of craft knowledge by hugely capitalized and efficiently organized capitalist entrepreneurs. Yet the route taken here involves the intensive training of the five senses of the *buyer*, rather than the making explicit of formerly tacit knowledge and the reorganization of the workplace in ways that fragment the labor process and reduce the skill content of the work. When Fan discusses techniques, it is without any intention to transform them: at one point, he remarks that weavers in a given place do not properly starch their cloth, but his advice to buyers is to avoid the product or to use it for purposes where the fault does not show, not to reform their practice.

No matter how successful—and agents like Fan Tong controlled an industry that produced about 40 million bolts (roughly 120 million square yards) of cotton cloth per year—this form of indirect control over the production process lost out against the "encyclopedic" project of exhaustive description (Xu and Wu 2000). From the 1890s on, we can observe a move towards ever more accurate and detailed writings on craft work, now clearly motivated by the intent to grasp and transform production. A large number of factors contributed to this shift: the legacy of mid-Qing statecraft and *kaozheng* traditions; the boost given to practical scholarship by the translations of Western scientific works; the growth of a cosmopolitan scientific community in Shanghai; the availability of new information-processing techniques (lithography, photography, chemical formulae, statistical tables, etc.); and above all, the realization that China needed to compete economically with the industrial nations of the West and Japan.

[35] I am grateful to Professor Qiu Pengsheng of the Academia Sinica for giving me a copy of the entire manuscript.

Let us briefly review this change in the case of papermaking; developments in other industries followed a similar trajectory.[36] An early indication of a growing interest in production technology comes from the work of the reformist official Chen Chi, who in 1896 wrote approvingly of two scholars who "had the strange idea" to buy land, plant bamboo, and open a large paper workshop (Chen 1997). A few years later, the novelist and self-trained chemical entrepreneur Chen Diexian (better known under his pen name Tianxu Wosheng, "Heaven Bore Me in Vain") wrote a reform proposal for the native paper industry of Jiangxi.[37] In the following years, Chen and other popularizers of scientific learning wrote widely about "household knowledge" and craft technologies, including papermaking, in such journals as *Healthy Home* (*Jiankang Jiating*) and *Ladies' Journal* (*Funü Zazhi*). The first book-length treatise on manual papermaking I have been able to locate is Luo Ji's (1935) *Zhulei Zaozhixue* (Bamboo Papermaking), a text that follows traditional conventions in its writing style and presentation but is entirely modern in its emphasis on hands-on experimentation. The 1930s and 1940s saw the publication of book-length studies on the paper industries of Fujian and Sichuan (Lin 1944; Zhong et al. 1943), as well as hundreds of journal articles on local paper industries. This very intensive mapping effort continued into the first years of the People's Republic, especially the late 1950s, when the Great Leap Forward campaign revived interest in cheap, local, manual technologies. In the early 1960s, the mapping of traditional craft technologies was complete. Not coincidentally, most Chinese handicraft industries were phased out at that time.

2 Conclusion

Most of the economically useful knowledge of Chinese artisans (and of course Chinese farmers, a topic not discussed here) was transmitted orally or tacitly, without recourse to writing. Such knowledge was physically stored in the hands and minds of practitioners and could be transferred to another person only through a form of apprenticeship, i.e., a long and arduous process of active embodiment under the guidance of an experienced practitioner.[38] It was embedded in social relationships, often in such ways that the mastering of a craft was inseparable from the learning of a social role. Physical embodiment and social embeddedness did not impose any significant limits on the transmission of knowledge *across time*: as long as the next generation of practitioners came from the same families or the same community, face-to-face

[36] The clearest indication of the interest in rural industries is the growing number of survey reports in specialized journals. In Sichuan, *Sichuan Yuebao* (Sichuan Monthly, published 1932-1937) and *Sichuan Jingji Yuekan* (Sichuan Economic Monthly, 1935-1949) published hundreds of detailed reports on industries ranging from pig bristle processing to modern mining. See also Bell (1999), for a detailed discussion of technical reform (involving the replacement of tacit by explicit knowledge) in the Wuxi silk industry.

[37] Chen's text, *Zaozhi gongcheng shixi jiangyi* (Teaching materials on papermaking technology) is discussed in Dai Jiazhang, p. 224. I have been unable to locate the original.

[38] Ingold convincingly argues against the notion of skill "transfer." Novices do not learn primarily through imitation of the master but through their own perceptual engagement with their surroundings, a process in which they actively "grow" their skills—albeit under the guidance of a master.

transmission was more convenient than relying on graphics or writing. Tacit transmission *across space* was more problematic, as it required the movement of people or objects rather than of textual or graphic information. Yet in the paper industry at least, this does not seem to have imposed any real constraints: technical information traveled quickly and over long distances, either through the migration of skilled workers or through the reverse engineering of sample goods supplied by merchants.

Writing played a role in the transmission of practical knowledge, but not necessarily in the ways we might expect. The texts that we today recognize as technical writings—texts like the *Tiangong kaiwu* or Hu Yueyun's *Zhi shuo*—were unlikely to be accessible to artisans, although we cannot exclude the possibility of a trickle down from the literati readers of gazetteers or *biji* literature to local artisans. If practitioners used written texts, these were most likely to be of a ritual or religious nature, or manuscripts containing notes, sketches, mnemonic rhymes, etc., perhaps passed on from parent to child or master to apprentice. Such texts were not self-contained instructions; they needed to be explicated, emended, and enacted by a skilled person who had already absorbed their meaning.

There is nothing uniquely Chinese in the predominance of tacit or oral over textual information. European industries, including ones that are associated with modern industry, also relied heavily on tacit skills. For example, iron puddlers—described as "key character[s] of the British industrial revolution"—relied exclusively on tacit skills transmitted along family lines (Rydén 1998). In the case of coal mining, another crucial industrial revolution technology, it has been suggested that it was abundance of coal skills rather than the abundance of coal itself that gave Britain its competitive edge.[39] Recent interpretations of the British industrial revolution have found tacit skills, typically underpinned by ethnic or occupational subcultures, in a large number of small industries (Berg 1991). If China was unique, it was not in the centrality of tacit skill for a large variety of production processes but in their long survival and rapid transformation in the twentieth century.

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