Emergence of Engineering as a Discipline in Modern China: Separation of Confucian Liberal Learning from Technique

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Abstract

The emergence and evolution of engineering education in China during the formative period 1902-1922 involved three historical stages. From 1902 to 1911, engineering was established as an independent discipline, but crucial links were retained with other fields and bodies of knowledge, and particularly Confucian traditions. The period 1912 to 1916 witnessed the separation of knowledge rather than integration, and the breaking of relations between engineering and humanities, including cancellation of the Confucian classics. From 1917 to 1922, some independent engineering universities and colleges were born, as the educational system reform recognized the legitimacy of the university organized around a single field. For each stage, influences on engineering education are discussed based on the historical context, which shifted China from traditional society to modern society. The paper also discusses how these early changes had a lasting influence on the development of Chinese engineering education, and reflect key tensions that remain relevant in current reform and policymaking efforts. Our account is based mainly on primary sources (e.g., original policy documents) and secondary scholarship. The main audiences for this paper include historians of engineering and engineering education, engineering educators wanting to learn more about the development of Chinese engineering education, and engineering education researchers interested in international comparative studies.

Keywords: China, discipline formation, engineering education, history, modernization

Introduction

Three school systems at the end of 19th century and the beginning of 20th century served as key foundations for the initial establishment of China's engineering schools. During the 20th century, engineering would in turn become one of the most important fields of higher education in China. The renewal of the educational system in early modern China involved three formative policy phases – namely the "*renyin kuimao school system*" (1902-1911), "*renzi kuichou school system*" (1912-1916), and "*renxu school system*" (1917-1922) – that reflected two different approaches to situating an emerging discipline of engineering within the broader landscape of Chinese higher education. This paper examines the three educational systems, including the implications of each in relation to the establishment of engineering as an academic discipline in early modern China.

As we discuss, this historical period has lasting importance for the development of engineering education in China. Of particular note is a fundamental and rapid shift from a more holistic and integrated understanding of engineering and engineering education to a highly segmented and compartmentalized approach adapted from the West. The early holistic view of engineering education considered Confucian "liberal learning" (i.e., training in Confucian traditional values and classics) as fundamental to any education, including in engineering. This approach had some important parallels with the liberal education model with origins in ancient Greece, which aimed to cultivate good people for the common good. In this sense, practicing engineering was therefore one way among many to promote Confucian values for national development. Hence, a good engineer had to comply with traditional Confucian values. In contrast, the later segmented

view of engineering education saw Western science and engineering and Confucian liberal learning as two separate and incommensurable knowledge systems. Western science and engineering were supported by democratic and liberal values and they were treated as the means of questioning the lack of pragmatic values for the society in Confucian liberal learning. Thus, the philosophical foundation of engineering practice and engineering education shifted from Confucian liberal learning to the Western liberal and civil ethics. A good engineer first had to be a good citizen and responsible for the civil society.

However, this separation of Confucian liberal learning from technique may also bring challenges to engineering education practice in contemporary China. On one hand, Confucianism still impacts Chinese thinking and actions in personal and professional life. On the other hand, some fundamental ideas and assumptions embedded in the Western engineering education pose challenges to Confucian traditions of teaching and learning which are remain evident in Chinese classrooms. For example, it remains unclear how team-based, active, and student-centered pedagogies in Western engineering education can be adapted for "Confucian classrooms" and "Confucian learners" where teachers are assumed to play a dominant role and students are largely subservient and reactive. Perhaps even more relevant for the current case are questions of content, including whether and how engineering students in the U.S., China, or any other country should be challenged to grapple with the bigger philosophical, cultural, social, and humanistic issues relevant to both life in general and professional work in particular.

This paper provides analytic themes and an important case for historians of engineering education, engineering educators who want to learn more about the development of Chinese engineering education, and engineering education researchers who are interested in international comparisons of engineering education. It is also hoped that this work represents a step toward developing a more nuanced historical-cultural approach to defining and resolving problems and contemporary challenges in Chinese engineering education and professional practice.

Historical Context

The late 19th century and early 20th century was a significant period for engineering education in many parts of the world. For instance, countries such as the U.S. and Great Britain experienced a movement away from work-based modes of education (e.g., apprenticeship) and toward more formal modes of education.[1-2] Additionally, the rise of the engineering sciences started around this time, with older hands-on and craft methods replaced by greater emphasis on mathematical modeling and scientific analysis.[3] This trend was also reflected in the emergence and growth of new science-based subdisciplines like electrical and chemical engineering. These trends were in turn accompanied by matching changes in engineering courses and curricula, with students spending more time in classrooms and laboratories rather than machine shops.[4] These developments represent the emergence, especially in the Europe and U.S., of a dominant system of modern engineering training that was increasingly scientific and analytic. This was also synergistic with a more general turn toward rationalism, empiricism, and positivism, both in universities and in society more generally.

Yet one important question that remains is whether such a system – either with or without its attendant Western intellectual and philosophical foundations – was readily transferable to a very

different national/cultural context, e.g., that of a traditionally Confucian China that was entering a period of intensified modernization during this same historical period. That is, how were Western approaches to education, both in engineering and more generally, compatible with local sociocultural elements represented by Confucian liberal learning. Addressing these questions first requires a review of some key educational policies from the time of the late Qing dynasty and early Republic of China.

Shifting Models of Engineering Discipline Formation

Renyin Kuimao School System (1902-1911)

"*Authorized School Regulation*", led by Confucian reformers Zhang Baixi, Zhang Zhidong, and Rong Qing, was the first school system officially promulgated and nationally implemented in early modern China. Engineering education belonged to two tracks in the *kuimao school system*, professional education and higher education. The former was intended to train technical workers and other specialists requiring less intensive education, including for industry needs, and was divided into three levels of schooling: preliminary, secondary, and higher level. The higher education system, on the other hand, prescribed that the university disciplines were divided into "Confucian classics, politics and law, literature, *gezhi* (academics of studying from the physical world [akin to science]), medicine, agriculture, engineering, and commerce." This new policy also indicated that "the previous eight disciplines must be established wholesomely at the Imperial University [now Peking University]. If any other province establishes a university in the future, the university will not be demanded to establish the whole eight but at least three disciplines in accordance with the system."[5]

From the perspective of discipline formation, dividing the higher education system into eight disciplines endowed engineering with independent discipline status, with significant implications for the subsequent development of Chinese engineering education. As noted by Shi Guiquan in his monograph: "the national standards and norms of Chinese higher engineering education had been established, and ended the historical period when the Chinese engineering education institutions had been established scattered, fragmented and drifted outside the formal national school system as of the 1860s."[6] However, during that period time, it should also be noticed that Confucian liberal learning was considered as fundamental to teaching science and engineering. Even more, the purpose of learning science and engineering was still highly influenced by Confucian ideas. For instance, as the Chinese translation of science, *gezhi* was taught by neo-Confucian scholars to students as a way to link rules governing specific phenomena with unifying Confucian precepts.

Renzi Kuichou School System (1912-1916)

After the establishment of the Republic of China in 1912, two educational objectives of the late Qing dynasty were abolished, namely "loyalty to empire, loyalty to Confucius", in accordance with the founding aims of the new regime. Meanwhile, the leaders of the Republic promulgated a series of educational laws and regulations in the form of the "*School Systematic Ordinance"*, such as "*University Ordinance"*, "*Special School Ordinance",* "*Industry-specialized School Discipline"*, "*University Regulations"* and so on, generally referred as the *renzi kuichou school*

system. The reforms reorganized the system of disciplines based on a Western model. They also involved cancellation of the Confucian classics, the contents of which were redistributed in various liberal arts disciplines. Further, "*gezhi*" was renamed as *sciences*. And as also indicated in the new policy documents, universities were to be organized around one of three possible organizational models: "The university encompassed liberal arts, science, law, business, medical science, agricultural science, and engineering. The university is given priority to liberal arts and sciences. To become a university should meet one of the three criteria, first, liberal arts and sciences should be established identically; secondly, the liberal arts should be established along with law and business; thirdly, sciences should be established along with one or two of following three disciplines, medical sciences, agriculture, and engineering."[7] As this suggests, schools combining engineering and the liberal arts were not favored in the new framework.

From the Modified University Ordinance to the Renxu School System (1917-1922)

A third major educational policy that had a critical influence on engineering discipline formation was the "*Revised University Ordinance*" established by the Ministry of Education in 1917. The ordinance indicated seven key disciplines, where "higher educational institutes with more than two disciplines can be called 'university', otherwise 'single-disciplinary university.'" In 1922, the *renxu school system* further prescribed that "higher educational institutes can establish several disciplines or only one discipline. The higher educational institute with one discipline was called a 'single-disciplinary university', such as medical university, law university."[8] This simple prescription recognized the legitimacy of the "single-disciplinary university", which in turn gave rise to many independent engineering universities. Aside from a few newly established universities, the rest of the engineering universities were upgraded from what had previously been industry-oriented universities.

The Nationalist government promulgated a new "*University Organization Ordinance*" and "*University Regulations*" in 1929, both of which demanded comprehensive development of the universities. More specifically, these documents included prescriptions such as "higher educational institute with three colleges can be called 'university'", and "university education should focus on the principle of pragmatic disciplines, must include college of science, or at least one of the following colleges, such as college of agriculture, college of engineering, or college of medicine." Yet as these passages make clear, these new policies did not fundamentally change the status of engineering as distinct from other academic disciplines, nor the isolation of engineering from the liberal arts.

Two Approaches to Engineering Formation in Confucian Context

In addition to economic and political factors, another important prerequisite for engineering becoming part of the Chinese educational system was acceptance by the new intellectual elite class, who ultimately came to promote and widely popularize engineering knowledge and the engineering profession. This new group included Zhang Zhidong, Wei Yuan, Lin Zexu, Zheng Guanying, Wang Tao, and Sheng Xuanhuai, who were supporters of industries and the main policymakers of the *kuimao school system*, as well as Yan Fu, Kang Youwei, Liang Qichao during the *Westernization Movement*, and Cai Yuanpei and Hu Shi during the *New Culture*

Movement. This social class acted as a backbone for promoting engineering education during these formative periods.

One major issue confronted by the elite intellectual class was how to cope with the relations between Confucian liberal learning, culture, and educational approaches, on one hand, and modern engineering knowledge, on the other, which remained closely linked to the West. Accordingly, Confucian reformers made explicit efforts to address these tensions, with special awareness of the unique structure of Chinese society.[9] For instance, the founding objective of *kuimao school system*, or "*jingshi weiji, xixue lianqi yi neng"* ("Confucian studies as basis, and Western cultures as subsidiary for cultivating technical skills"), was consistent with Zhang Zhidong's ideology of "*zhongti xiyong*" ("Chinese learning as substance and Western learning for practical use").

Hence, engineering was still strongly linked to the "Confucian classics" in the *kuimao school system*, even though it had independent discipline status. For example, engineering learning could only occur after *"xin shu yi gui yu chun zheng"* (one's heart is pure and rectified) and "*yi zhongguo jingshi zhi xue weiji*" (training in Chinese Confucian classics as fundamental). To achieve this kind of foundational moral and intellectual development, it was assumed that the Confucian classics were covered in all levels of schooling, from the *small xuetang* (elementary schools) to preparatory colleges and universities. In fact, the policy documents indicated that treatment of Confucian teachings in elementary schools and universities should be well-aligned, especially in order to rectify human mind and human nature.[10] Engineering was more specifically treated as "*yineng*" ("artistic skills"), which played a role of "*yishi shiyong*" ("adapting to practical needs") in higher education. This kind of style embodied the ideology of "*tiyong buer*" ("inseparability of substance and function"), i.e., traditional Chinese learning as substance cannot be separated from Western engineering as function.

This approach was also consistent with traditional Chinese approaches to classifying different types of knowledge, which allowed for a unification and coordination of engineering knowledge and Confucian classics. This kind of knowledge classification is based on a divergent structure around a center, reflecting the integration of knowledge. All fields are organized around a core, which was viewed as a superior approach given its potential for being "*xunhuan xiangji yi weiyong*" ("being integrated without any barriers"). Because engineering is comprehensive, involves complexity, and attempts to meet human needs, it seems potentially well-aligned with this way of organizing knowledge, which promotes coherence and convergence between scientific and humanistic knowledge in engineering education. Yet based on establishment of "a rational engineering curriculum system," engineering students were required to take compulsory courses related to specialized technical topics in order to avoid achieving breadth without sufficient depth.[11] This approach was consistent with a traditional Chinese view that "natural sciences cannot be isolated. And if it was separated from humanities, it would be looked down upon and wouldn't go further. There was also no ideal to pursue humanities by itself. "[12]

A second type of approach to engineering formation emerged during the aforementioned "*renzi kuichou" and "renxu"* school system reforms. To begin, the Confucian classics were cancelled, which eroded the unifying view of knowledge characteristic of the previous system, and led to major changes in how engineering was related to other disciplines. For example, courses like

"*renlun daode*" ("human ethics and morality") and "*jingxue dayi*" ("interpretations of Confucian texts") were cancelled at the stage of preparatory college, which meant that students were encountering less and less Confucian learning prior to starting their engineering studies. Additionally, the reformed school system prescribed that preparatory colleges should "attach to but not be independent of the university", and students could not enroll in undergraduate engineering programs until completing the following courses: foreign language, Chinese, mathematics, physics, chemistry, geology and mineralogy, drawings, surveying.[13]

Additionally, the academic boundaries between the humanities and sciences became more distinct. With reduced emphasis on the Confucian classics, there were fewer opportunities to integrate humanities and science. As a "technique," engineering clearly belonged to the sciences, expanding the gap between engineering and liberal arts. Thus, the *renzi kuichou school system* prescribed in general that "university should teach advanced scholarship, cultivate excellent talents, serve the country", and yet a growing divide between the disciplines meant that these objectives might be that much more difficult to achieve.

The concept of "*xueshu erfen*" ("learning and technique were separated") was also applied to the engineering discipline planning in both the *renzi kuichou* and *renxu* school systems. This reflected Cai Yuanpei's educational philosophy of "*xue wei jiben, shu wei zhigan*" ("learning as the trunk and technique as the branch"). For instance, it was argued that "agriculture, engineering, medicine, pharmacy, law, business, and other applied sciences are based on liberal arts and sciences. Research in these applied sciences is ultimately based on liberal arts and science."[14] Additionally, it was proposed that "the full university should include all disciplines, with the convenience for interrelating each other."[15]

Yet Cai Yuanpei's educational philosophy changed after 1917, reflecting strong influences from the German system of higher education and university model. As one of the most important educational reformers in modern China, Cai Yuanpei was trained with Confucian liberal learning in his formative years. But later he went to study philosophy, psychology, and art history in the Universität Leipzig of Germany and visited other cities and schools in Europe. When he returned to China from Germany, he served in senior administrative roles in the government and later was appointed the President of Peking University. His experiences studying and living in Europe were likely pivotal influences that spurred his use of Western scientific and analytic approaches to reorganize Confucian scholarship and reform Confucian educational traditions.

More specifically, Cai Yuanpei believed that "*xue*" (learning) and "*shu*" (technique) differed fundamentally in their nature. The former was concerned with theory, the latter with application. Hence, he came to believe that "*xue*" and "*shu*" should be taught in different colleges and schools. Under the guidance of this idea, engineering was separated and isolated from science – not to mention the liberal arts – even more thoroughly. In this new model, the university still encompassed all areas of knowledge, and all the elements of truth, goodness and beauty were still covered by the full spectrum of disciplinary academic pursuits. However, "each element is now treated as a separate objective to pursue. Consistency gives way to separation. Diverse programs are loosely coupled to a single management organization."[15]

Conclusion

As briefly reviewed here, a series of three educational policy reforms represent key formative events for the emergence of engineering as an independent academic discipline in early modern China. The first of these reforms gave a glimpse of what a more integrated model of education might look like, i.e., one where engineering training was more closely linked to traditional Confucian learning and knowledge. And yet, through the second and third forms we find another kind of model prevailing, namely one that bounded engineering as closer to (and yet partially distinct from) science, as well as separable from broader social and cultural considerations. In countries like the U.S., this tendency was reflected in development of formal engineering training as both increasingly scientific and divorced from the liberal arts and humanities.

This trend would largely continue through the Nationalist period, where the development of engineering schools remained very utilitarian and focused on national development priorities, such as the building of industry and infrastructure.[16] And then, following the formation of the People's Republic of China in 1949, another dramatic wave of engineering education reform was advanced based on still other ideological foundations, namely that of Marxism and Maoism.[17] Even more recently, China's engineering education system appears to be following a path of increasing harmonization with *de facto* international standards, e.g., through China becoming a signatory of the Washington Accord. Yet through all these periods, we find an ever-widening gap between Confucian traditions of culture and learning and modern engineering training.

The consequences of this gap are not entirely clear, and it is worth asking whether something was lost when higher engineering education in China turned so decisively away from Confucianism beginning in the early Nationalist period. Indeed, Wang and Zhu have shown how traditional Chinese patterns of thought remain very relevant for many different dimensions of modern engineering practice, particularly in Chinese cultural contexts.[18] Other commentaries have suggested that certain Chinese cultural values, e.g., that of Daoism, could help inspire creative solutions to many of China's increasingly urgent environmental and sustainability challenges.[19] As these writers suggests, when it comes to educating engineers, there might need not be a contradiction between using different "*dao*" ("natural and moral order of the universe") to shape the engineer's soul while at the same time leveraging the "*qi*" ("instruments" or "means") of engineering technology.

Exploring such intersections of native culture and seemingly "universalized" engineering technique may indeed reveal new models of engineering training and professional practice that are better tuned to contemporary needs and realities, both locally and globally. We argue that Confucian liberal learning may help us better understand how engineering as a global practice could better "make sense" to people and society in the Chinese context. Indeed, one critical issue today in Chinese engineering education and practice is an apparent lack of the sort of solid ethical foundation that is frequently viewed as a core, defining feature of a modern profession, per Western standards. Confucian liberal learning remains a promising resource that could help develop personal and professional integrity among Chinese engineering students and practicing professionals, including in terms of both "micro-ethical" and "macro-ethical" considerations.[20] At the micro level, Confucianism provides guidelines for how to appropriately deal with human relations, including the relations between engineers and other stakeholders. At the macro level, a

Confucian outlook offers processes and standards to evaluate the sociopolitical ramifications of engineering projects in terms of their roles in supporting common social goods, as well as harmonious relationships between humans and the natural world. Reuniting Confucian liberal learning with engineering technique in these ways could represent a profoundly transformative step forward for Chinese engineers, Chinese society, and the world.

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