



Industrial Ecology Education at Wuhan University

Authors

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Abstract

China requires industrial ecology (IE) skills and knowledge to deal with the contradiction between rapid economic growth and subsequent environmental pollution and resource depletion. Industrial ecology education was introduced in China in 1997 and now a few Chinese universities offer IE courses. Wuhan University is one of them and since 1999 has committed itself to promoting IE education. The university offers different curricula for different majors at all levels: undergraduate, master's, and doctoral. Between 1999 and 2004 more than 5,000 students received IE education at Wuhan University. Although inadequate human resources and a lack of relevant textbooks present challenges to further developing IE education in China, as more universities pay attention to IE, more courses will be developed. It is believed that IE education in China will blossom in the near future.

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Summary

China requires industrial ecology (IE) skills and knowledge to deal with the contradiction between rapid economic growth and subsequent environmental pollution and resource depletion. Industrial ecology education was introduced in China in 1997 and now a few Chinese universities offer IE courses. Wuhan University is one of them and since 1999 has committed itself to promoting IE education. The university offers different curricula for different majors at all levels: undergraduate, master's, and doctoral. Between 1999 and 2004 more than 5,000 students received IE education at Wuhan University. Although inadequate human resources and a lack of relevant textbooks present challenges to further developing IE education in China, as more universities pay attention to IE, more courses will be developed. It is believed that IE education in China will blossom in the near future.

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Introduction

Industrial ecology (产业生态学 *chan ye sheng tai xue*) has developed rapidly in the past 20 years, and as a result IE education has attracted attention in institutions of higher education throughout the world. Many Western universities offer courses and training programs on IE for students from diverse disciplines (Marstrander et al. 1999; Baas et al. 2000). The International Society of Industrial Ecology lists more than 75 institutions in their summary of degree programs in IE (ISIE 2006). Efforts to popularize IE theory and methods have more recently taken hold in Chinese institutions. Several universities, colleges, and research facilities are actively pursuing IE education.

In 1997 Lu Zhongwu at Northeast University began educating doctoral students in IE with a research project on material recycling in metallurgy processes. In 1998, Tsinghua University added IE courses to its chemical engineering master's program. Faculty there also created courses on research and design for eco-industrial parks (Deng and Wu 2002). Since 1999 Wuhan University has offered IE courses to master's and doctoral students majoring in environmental science or environmental engineering. The College of Resource and Environmental Science at Wuhan University has committed itself to accelerating the development of IE education in China.

The Political, Economic, and Industrial Context for Industrial Ecology

For the past two decades China's economy has experienced an average growth rate of 8%, which has attracted wide attention throughout the world. This achievement, however, came at significant cost to the environment and has depleted natural resources. For many years the economic development model featured high input, high consumption, and serious pollution, but low output. Resource consumption per capita as a function of gross domestic product (GDP) is eight times of that in OECD countries (Xie 2004a). Because of this resource consumption, China faces severe resource shortages and environmental pollution. Using water resources as an example, re-

sults from monitoring cross sections of seven river systems in China show that 44% are of low quality. Moreover, more than 65% of cities in China face water shortages (Xie 2004b).

The Chinese government has realized the danger of the traditional development model of high input and low output and has taken a series of actions, including legal restrictions, policy positions, and public education, to control resource waste and environment pollution. The government has taken several steps to push sustainable development and the circular economy (循环经济 *xun huan jing ji*). The idea of a circular economy is a hot topic in China. The China Council for International Cooperation on Environment and Development (CCICED) established a special task force to study the circular economy. This task force explains that the concept of circular economy emphasizes closing the materials cycle within the economy. In a traditional industrial economy, material flow patterns are one-way, linear processes that consist of "resource—production—consumption—disposal." In this kind of open-loop, linear economy, people extract materials and energy from the planet, then release them as pollutants and wastes to the air, water, and soil, treating the earth as a "sewer" or "garbage can." In comparison, the circular economy promotes a development pattern that attempts to be more harmonious with the earth. The main purpose is to organize economic activities in a closed-loop process of "resource—production—consumption—secondary resource." All materials and energy can be used rationally and continuously in sustained economic cycles; hence, harmful effects to the natural environment can be minimized (CCICED 2003). A circular economy is essentially an eco-economy. Its main element is an industrial ecological chain; the carrier is an ecological industrial park; the most important measure is cleaner production; the inherent requirement is material reduction; and the goal is to realize the harmonious development between the economy and ecology (Bao 2005; Yuan et al. 2006).

Since 1998 cleaner production has been promoted and environmental management systems have been authorized and certified. China supported the development of the environmental industry and the recycling economy (Zhu 1999).

In 2002, a Cleaner Production Promotion Law was promulgated in China. This law requires that the State Council and the local people's governments at or above county level must infuse cleaner production into plans and programs for national economic and social development. The country is committed to encouraging social groups and citizens to participate in increasing public awareness with respect to cleaner production (TSCOTNPC 2002). In 2004, Premier Wen Jiabao stated in his Government Work Report that China would energetically promote the recycling industry and cleaner production and would protect Chinese land and resources in accordance with the law and utilize them rationally (Wen 2004). Wen Jiabao restated in the next Government Work Report that China would be focused on saving energy, water, and materials in key industries. China would encourage the development of energy-efficient, environment-friendly automobiles, and housing and public buildings that use less energy and land. Additionally, he indicated that China would develop the recycling sector of the economy and would address resource exploitation and increase comprehensive resource utilization and recycling, including utilizing waste materials (Wen 2005). All of the measures described herein show the confidence of the Chinese government in enforcing sustainable development strategies, in which IE plays a fairly significant role.

In its policies, the Chinese government encourages resource regeneration and waste recycling industries through taxation and advocates green consumption to promote the circular economy (TSCOTNPC 2002). In addition, 10 eco-industrial parks have been established to promote IE, and funds related to environmental and resource research have been increased.

The government advocates the new green consumption concept and is using a public information campaign to inform people about the environment and the resource crisis and to encourage people to take part in environmental protection activities and waste recycling. This year, to instill the idea of sustainable development in the daily lives of common people, the national television channel offered a special 100-day program to instruct audiences on how to save water and electricity, and to reuse wastes.

In concert with governmental measures, the business world has actively participated in circular economy activities. Some new eco-industrial parks are under construction and many enterprises have started cleaner production. By the end of 2003, more than 400 enterprises representing 20 industries in more than 20 provinces started auditing for cleaner production. More than 5,000 enterprises have obtained ISO14000 certificates and hundreds of products have been granted environmental labels (Xie 2004c). Some provinces have obtained environmental benefits by adjusting their industrial structure. Many enterprises have implemented technological innovation and are reusing wastes in large quantities, thereby reducing their raw material use as well as their waste generation.

People with IE skills and knowledge are needed to assist with policy formulation and promotion, industry structure reconstruction, and technological innovation in industry. This means that educational institutions in China need to generate many graduates with these skills as soon as possible. China needs talented people who are committed to the circular economy concept and who have professional knowledge in management, economic, scientific, and technological fields. Educational programs such as the one described here will contribute greatly to generating the individuals necessary.

Teaching IE at Wuhan University

Higher education in China consists of three levels: bachelor's, master's, and doctoral degrees. All students complete a mix of compulsory and elective courses in their degree programs. As presented in the introduction, several universities have been offering IE courses since 1997. In most of these institutions, IE is taught at the graduate level in focused programs. The effort at Wuhan University is unique because it is emphasizing promoting IE more broadly and it is the only university in China to open IE courses to students at all levels and in all majors. The philosophy behind this approach is that it provides students with at least a rudimentary understanding of IE concepts so that they can apply them at some point in the future.

Table 1 Student participation in IE education at Wuhan University 1999–2004

Student level	Major	Number of students	Compulsory or elective	Format	Beginning year
Undergraduate	EE & ES*	180	Elective	Course	2001
		3	Compulsory	Thesis	2001
Master's	EE & ES	504	Compulsory	Course	1999
		3	Compulsory	Thesis	2001
		100	Compulsory	Course	1999
Doctoral	(advanced studies)				
	EE & ES	60	Compulsory	Course	1999
	All majors (incl. ES)	4,800	Compulsory	Course	1999
Total population		5,590			

*Note: EE = environmental engineering. ES = environmental science.

When it first began publishing in 1997, the *Journal of Industrial Ecology* presented readers with a list of topics to describe its focus. Wuhan University faculty utilized this list to identify the core elements for IE education. These include material and energy flows, life-cycle assessment, environmental policy, and design for environment, among other subjects. Based on feedback from the initial courses and information in the text *Industrial Ecology* (Graedel and Allenby 2004), the faculty have expanded the curriculum to include topics such as eco-industrial parks and extended producer responsibility. The faculty also added a research element.

Wuhan University made the first IE courses compulsory for master's students in Environmental Science and Environmental Engineering beginning in 1999. In addition to teaching courses, staff supervised those writing graduate papers on life-cycle assessment.

Between 2001 and 2004 three master's students completed research projects in IE. Their subjects were *Life-cycle Assessment on One-off and Collective Sterilization Dishware* by Sun Xujun (2001); *Life-cycle Assessment on Driven Connecting Rod of Motors Produced through Different Processing* by Wang Xiaobing (2002); and *Design and Realization of Software System for Life-cycle Assessment* by Zhang Yaping (2004). By June 2004, the number of master's level students trained in IE at Wuhan University had reached 507. Table 1 provides a summary of the various educational efforts between 1999 and 2004.

Also beginning in 1999 the list of courses available to doctoral students specializing in Environmental Science or Environmental Engineering included topics such as IE, green chemistry, and environmental economics. Furthermore, the faculty encourage students to pursue research subjects related to IE. At the time of writing, two doctoral students were engaged in IE research.

All doctoral students in Wuhan University attend a 4-hour lecture covering emerging issues in environmental science. The lecture focuses on global environmental change and IE, including its history, methods, and tools. Professors at Wuhan University recognize that IE is an interdisciplinary science and that industrial development cannot be separated from social, political, and economic realities. For this reason, IE education should not be restricted to a specific college or department (Starr 1992). It is effective to spread IE knowledge to doctoral students throughout the university. This group is relatively small in number, but these individuals are rapidly absorbing new knowledge and are influential in society; thus, Wuhan University decided to require IE education for doctoral students from all majors. Detailed knowledge cannot be realized in a 4-hour lecture, but this approach does allow the IE concepts to penetrate into other specialties. The student interest is clear, as at the end of the lecture, many students, mostly majoring in law, economics, policy, or engineering, discuss with the lecturer how to integrate IE concepts

into their research subjects, and have asked for more information concerning IE. Wuhan University faculty hope that these doctoral students will internalize IE concepts, and express them in their future work and research. Most of these students will serve as professors in colleges, researchers in institutions, officers in various levels of government, or policy researchers in the near future. As of June 2004, the number of doctoral students at Wuhan University trained in IE had reached 4,800.

Industrial ecology education for undergraduates began in 2001 and was limited to Environmental Engineering and Environmental Science students until 2005. Like the graduate programs, the undergraduates may select IE as a subject for their graduation paper. Elective IE courses are available for undergraduate students majoring in Environmental Engineering or Environmental Science. Sample topics are industrial metabolism, life-cycle assessment, and eco-industrial parks in the circular economy. For the sake of better understanding IE concepts, students take these in their 3rd and 4th years because by then they have a solid foundation in their specialty.

Three undergraduate students have selected IE for their thesis subject. Their papers are: *On Life Cycle Assessment and its Application* by Zhang Yaping (2001); *Industrial Ecology Practice: Establishment and Development of Guigang Eco-industrial Demonstration Park* by Chen Yanqiong (2002); *Environmental Management Information System of an Eco-industrial Park* by Yang Peng (2004). As of December 2006, the number of undergraduate students trained in IE had reached 783.

In 2005, Wuhan University began offering a general elective IE course for undergraduate students throughout the University. This course provides a broad overview and covers the connections between human behavior and the natural environment, the history of IE, and several methods and tools used in IE. In its first term, 120 students representing almost all colleges at the university selected this course.¹

In addition to promoting IE education on campus, Wuhan University has offered IE courses to off-campus students who are pursuing advanced studies in Environmental Science or Environmental Engineering. Immediate social effects can be achieved by adding IE education to

advanced-study classes because these are aimed at enhancing staff quality for businesses and government agencies. Three advanced-study classes have been arranged by Wuhan University in Hubei and Henan Province since 1999, in which 100 students have been trained in IE.

To more broadly popularize IE, professionals in Wuhan University are writing books, publishing papers, and working with industry. Wuhan University has published three books on IE: *Industrial Ecology—Theories & Application* (Deng and Wu 2002); *Green Passport—ISO 14000* (Zhang and Deng 2003); and *Life Cycle Assessment* (Deng and Wang 2003). Students have submitted their papers to journals and conferences on IE and the circular economy. Now Qingjing Chemical Industrial Ltd., a big corporation in Wuhan, is attempting to cooperate with Wuhan University to improve its material recycling rate. The College of Resource and Environmental Science and the College of Chemistry are planning to recruit several doctoral students to work together to help the corporation.

Challenges in Teaching Industrial Ecology

Notable distance exists between IE education in China and in other countries, although IE skills are needed domestically. Numerous problems await resolution with respect to the current level of IE education in China.

First, professors in this field are few and are not uniform in their levels of knowledge. Presently, IE curricula are only offered by a few universities in China. Moreover, those who graduate with doctorates and take up teaching IE are scarce. Generally, professors lack a comprehensive understanding of the integrative nature of IE because of their restriction within a particular research area. Therefore, training teachers should be a priority in accelerating the development of IE in China. One recommendation aimed at increasing the quantity and enhancing the quality of IE teachers in China is to identify professionals, both at home and abroad, who are engaged in IE research in various fields to conduct training.

Second, IE textbooks relevant to different majors are also inadequate in China. Realizing the benefits of IE education can only be achieved

through integration with other majors, so textbook content should be adapted for various majors. Faculty at the universities offering IE curricula have developed their own textbooks to suit their needs. Wuhan University faculty created *Industrial Ecology—Theories and Practices* and use it as the basis for their teaching.

Third, too little participation from business enterprises is another factor impeding the development of IE education in China. Commonly, universities or scientific institutions that conduct research for enterprises or governments charge fees. It would be beneficial for students to conduct case studies for businesses for free, and this would enhance student analysis and problem-solving capabilities and would benefit the business.

Conclusion

Having realized the necessity of promoting IE education in China, Wuhan University is actively pursuing this. Faculty members have taken the initiative to offer IE courses to all majors at each level, which is a great contribution to disseminating IE education. Comprehensive courses for selected majors are another significant contribution. Unfortunately, inadequate human resources and a lack of textbooks challenge efforts to further develop IE education in China; however, as more and more universities pay attention to IE, more appropriate courses will be developed. With more university and government efforts, the problems discussed herein can be addressed piece by piece and IE education in China will blossom.

Note

1. Details of the topics covered in the required doctoral course, the master's level coursework, undergraduate environmental science and environmental engineering majors elective coursework, and the undergraduate general major elective course can be found in an appendix available as an e-supplement on the *JIE* website <www.mitpressjournals.org/jie>.

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