中国科学技术大学科学传播中心
公民科学素养与公共科学传播丛书

公民科学素质测评的理论与实践

Theories and Practices of Civic Scientific Literacy Evaluation

郭传杰　汤书昆◎主　编

◎美国科学与工程指标◎PUS概念的提出和演变◎欧洲晴雨表◎OECD国际学生评估项目◎中国公民科学素质测评的理论与社会基础◎中国公民科学素质概念模型与测评指标体系◎测评的流程设计与过程控制◎项目反应理论的应用◎面向创新型国家建设

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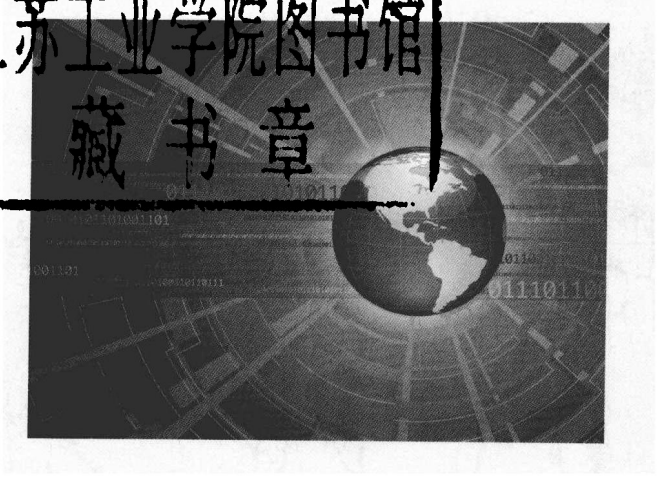

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内 容 简 介

本书系中国科学技术大学科学传播中心的研究专著，全面阐述了公民科学素质测评的理论基础与操作实践问题。第一章概述了美、英、日等国及欧盟“欧洲晴雨表”和OECD的国际学生评估项目（PISA）科学素质测评的成就；第二章从哲学、文化、政策、法律的视角讨论了我国当代公民科学素质测评的社会历史基础和文化价值；第三章论述了中国公民科学素质的概念模型以及科学知识、科学意识、科学能力三向度的测评指标体系；第四章结合一个省级区域实验样本调查和我国东中西部三个对比样本调查，介绍了公民科学素质测评实践的流程设计与过程控制；第五章讨论了公民科学素质的测试与评价方法，特别是项目反应理论及其在公民科学素质测评中的应用；第六章阐述了面向创新型国家建设的中国公民科学素质测评问题。

本书可作为广大科技工作者、教育工作者、社会工作者及政府相关部门公务员的推荐读本或培训教材，亦适合传播学、管理学等相关专业的本科生、研究生阅读。

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《公民科学素质测评的理论与实践》
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Abstract

The book is written by scholars of Center for Science Communication, University of Science and Technology of China, based on a research supported by Civic Scientific Literacy Evaluation for Constructing an Innovative Country Program sponsored by Chinese Academy of Sciences, and supported by Empirical Study on Chinese Civic Scientific Literacy Evaluation Indicator System Program by China Association for Science and Technology. Moreover, it is funded by the National Innovation Base for Sci-Tech History & Sci-Tech Civilization, which is a component of the National 985 Program of China.

The book consists of six chapters, in which theories and practices of civic scientific literacy evaluation are studied. Besides, the theoretical background and operation framework of the evaluation in China are elaborated. Chapter One summarizes the evaluation results achieved by some countries, e. g. U. S. A. , Britain, Japan, etc. and by international organizations, e. g. EU (Eurobarometer) and OECD (PISA). In Chapter Two, the historical basis and cultural value of Chinese civic scientific literacy evaluation are analyzed from the perspectives of philosophy, culture, policy and law. Chapter Three addresses the conceptual model of Chinese civic scientific literacy and proposes a three-dimension evaluation indicator system, consisting of scientific knowledge, scientific awareness and scientific capablity. Chapter Four introduces the procedures and process control in practicing the evaluation, based on the samples collected from a chosen province and investigation results from the East, Middle and West China. Chapter Five discusses various methods involved in civic scientific literacy evaluation, focusing on the Item Response Theory and its application. Chapter Six enumerates the problems in evaluating Chinese civic scientific literacy, which aims to promote the construction of an innovative country.

Chapter One Theories and Practices of International Civic Scientific Literacy Evaluation

Chapter One reviews the theories and practices of Civic Scientific literacy evalua-

tion involved in Science and Engineering Indicators of the U. S. A. , Britain's PUS (Public Understanding of Science), the European Public's Scientific and Technical Development in Eurobarometer, OECD's Program for International Student Assessment (PISA), and public understanding of S&T researches and evaluation in Japan.

In the part on Science and Engineering Indicators of the U. S. A. , the book reviews the history of American Civic Scientific literacy evaluation practice after the World War II. Three heterogeneous views exist in the period among the public, represented by trust, suspicion and involvement. The American government adopted a series of measures to guide the public's comprehensive understanding of science, for the purpose of guaranteeing a democratic decision process, as well as implementing the national science strategies.

Moreover, investigation results of Civic Scientific attitude, interest, and Civic Scientific literacy evaluation in Science and Engineering Indicators are analyzed. In 1957, Rockefeller Foundation, sponsored by National Association of Science Writers, investigated the public's basic scientific literacy. In 1972, the National Science Foundation made a survey on the public understanding of science and attitude towards science, and a series of biyearly reports named Science Indicator are released based on the survey results.

Researches are done on the development of Miller's public scientific literacy indicator system. In 1979, Miller's 3-dimension scientific literacy model was initially applied in U. S. A. In 1983, the 3-dimension scientific literacy model was openly published and in the 1998 the model was modified in a more comprehensive way. The three dimensions contain sufficient vocabulary to understand the basic science concepts in newspapers and journals, ability to understand the processes and essence of science exploration, and familiarity to the possible influence of science and technology on society and human beings.

In the part on Britain's PUS, the book elaborates the motivation and development of PUS in Britain. It is believed that the major motivation lies in reflections on the two World Wars and considerations on the environmental problem in the 1970s. In 1985, Royal Society's release of the report *The Public Understanding of Science* written by W. F. Bodmer represents the shape of PUS theories.

Four critical reports on PUS evaluation in Britain are introduced. Among them, PUS explains major definitions in the field of PUS, which provides a consistent format for the theoretical studies; 1995 Wolfendale's Report uses awareness and apprecia-

tion in elaborating understanding, and in it science is extended to a larger extent with technology and engineering. Moreover, social impact and government targets are emphasized. In Science and Society, new horizons arise and focus is put on the credit crisis of the public towards science. Science in Society proposes the concept and practice of public involvement in science and scientists' involvement in PUS.

Eurobarometer part analyzes the public opinion surveys on science and technology. The surveys are implemented for six times, including Science and European Public Opinion (1977), The European Public's Attitude to Scientific and Technical Development (1978), Europeans, Science and Technology (1989, 1992, 2001, 2005). Tenet, content and functions of the six surveys are discussed and it is concluded that the 1977 survey aimed to collect public opinions, and surveys done in 1989 and 1992 illustrated the transition from public opinion survey to PUS research. In 2001 Miller's 3-dimension model was adopted and survey in 2005 was more compatible to the current status of Europe.

In the part on PISA of OECD, the author reviews the origin of OECD international student evaluation program and 3 large-extent practices. The purpose lies in measuring the youth's literacy and constructing a framework in which comparisons can be done to reflect the effects of elementary education in member countries. By now, 3 wide-ranged evaluations are done in 2000, 2003 and 2006 respectively.

Analysis is done on the interpretation of PUS and indicator dimensions in PISA. It is found out that PISA mainly referred to Shamos' research in scientific literacy, and Bybee's four-layer elaboration on scientific literacy. Bybee puts scientific literacy into four layers: basic scientific literacy on the ground layer, and above it are practical scientific literacy, concept and processes, and multi-scientific literacy. Based on these studies, PISA indicator system consists of three dimensions of knowledge, ability and attitude.

In the part of Japan, two systems are introduced. One is the public opinion survey on science and technology implemented by Cabinet office for over forty years. The other is science and technology awareness survey adopted by Science and Technology Policy Institute of Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 1991 and 2001. Japan is featured by its emphasis on how to improve the public understanding of science, instead of attempting to implement the adapted versions of evaluation, which is the dominating practice in the international level.

In the end the chapter summarizes the development of civic scientific literacy con-

cept studies, features of PUS evaluation and implications.

Chapter Two Theoretical and Social Backgrounds of Chinese Civic Scientific Literacy Evaluation

Chapter Two mainly studies the theoretical basis and social background of Chinese civic scientific literacy, from the perspectives of philosophical background, cultural basis, policy targets and legal foundation.

In the philosophical background part, the book discriminates various repre sentative knowledge discourse right patterns in remote antiquity, antiquity, and contemporary times, and points out that in modern times, it is the S&T knowledge and literacy that decides the strength of discourse right from the individual to the whole country. Based on a reflection on the relations between "dao" (道) and "qi" (气) as well as "ti" (体) and "yong" (用), the significance of the two theories to the civic scientific literacy evaluation is identified. The evaluation should be life-oriented instead of science-oriented, focusing more on the science spirit and science awareness.

Cultural basis part analyzes the unbalanced state of profession structures and social classes, that of urban and rural areas, and that of the different regions. It is concluded that the civic scientific literacy evaluation in China should be adapted in accordance with the current status of China.

Through an analysis on the relationship between science and culture, it is held that scientific literacy should be included as a part of culture literacy, and evaluation system should consider the traditional features with the Chinese science and knowledge system, and understanding and definition of science, since different cultural backgrounds view science and technology in different ways.

Compression of time and space features the current development model of China. In the book the stimulation and representations of the belief are elaborated. It is pointed out that scientific literacy evaluation in China should also entail the concept of sustainable development, and accommodate more concepts on environmental protection and resources saving in the modern understanding of science.

Implication and features of the interest game epoch are analyzed from the perspective of justice-competitiveness relationship. Challenges to the universality and fairness of scientific literacy evaluation are discussed. It is believed that scientific literacy evaluation in China should set India's system as the base line and America's as the benchmark.

The part on policy objectives explains the strategy of "building a well-off society". Distance between the current status of Chinese civic scientific literacy and a well-off society requirements is distinguished. Civic scientific literacy evaluation will serve as a decision reference for the building of a well-off society.

The book also reviews the motivation and development of the target of establishing a harmonious society. The evaluation will provide important policy basis for the construction of a harmonious society.

Target of constructing an innovative country is also discussed in the book. The relation between the strategy and civic scientific literacy promotion is analyzed, and it is argued that civic scientific literacy evaluation is the basis for the construction of an innovative nation, following a self-oriented innovation road peculiar to China.

The legal basis and guarantee come from the constitution, specifically from the laws concerning the national obligations in developing education, promoting science development, extending cultural enterprises, cultivating talented persons, and protecting the public's rights in education and the public's freedom for participating in scientific research, literature creation and other cultural activities.

Promotion of the civic scientific literacy is the tenet of the Science and Technology Popularization Law. The law defines the connotation of civic scientific literacy, and provides protection for the management mechanism and social responsibility mechanism of the civic scientific literacy evaluation.

The auxiliary legal structure is analyzed, which includes laws concerning education, protection of the property of different groups, laws about sustainable development, laws dealing with natural disaster and social accidents, and laws about S&T popularization.

Chapter Three Civic Scientific Literacy Concept Model and Evaluation Indicator System in China

Chapter Three contains analysis on various interpretations of civic scientific literacy definition and its application. Moreover, principles, components and application suggestions for the civic scientific literacy evaluation indicator system of China are proposed.

In the first part, various definitions of scientific literacy are analyzed. James

B. Conant, an American chemist, in his 1952 book General Education in Science proposed the concept of scientific literacy for the first time in history. From then on, scientific literacy evolves from an education concept to a literacy promotion action, and various concept models and evaluation indicator systems are enacted accordingly.

W. J. McGuire's knowledge-attitude-practice (KAP) model focuses on the discrimination of individual literacy; B. Shen's practical-civic-cultural scientific literacy model, meanwhile, pays more attention to the overall function of the society. Knowledge-centered orientation represented by John Durant's concept-method-STS model illuminates both science popularization and PUS. While PISA's setting-knowledge-ability-attitude model, ability-oriented, highlights social and school education as well as public participation.

Different models illustrate the peculiar features of evaluation goals and social backgrounds with different nations and regions. Therefore, in our design of civic scientific literacy evaluation indicator system, goals of each model should be respected while cultural features of China shouldn't be neglected.

Design principles are listed as follows: the indicators should reflect current status and peculiar features of China; meanwhile, the indicators should be compatible to the international standards, so as to guarantee an effective comparison and cooperation.

Both consistency and adaptivity to the new developing needs should be covered in the system. The basic elements such as standards, subjects, measures, contents, forms and changes of results should be included. Besides, requirements for the construction of an innovative nation should also be considered.

The indicator system should comply with the national strategy targets, i. e. requirements for the establishment of an innovative nation, requirements set in the *Outline of National Action Scheme of Scientific Literacy for All Chinese Citizens (2006 – 2010 – 2020)*, and basic standards for the civic scientific literacy in China. Meanwhile, the feasibility should be considered as well. That is, indicator system can guarantee an effective survey, in which expression of various indicators is clear and sensible.

The components of the indicator system include: overall framework including goals, indicators at 3 dimensions of knowledge, awareness and capability, sub-indicators (level 2 indicators), and survey questionnaire (Table 3-1). The four layers constitute a complete and interactive organic body.

Table 3-1 Indicator System of Chinese Civic Scientific Literacy Evaluation

Objectives of evaluation	Level 1 indicators	Explanation of level 1 indicators	Level 2 indicators	Explanation of level 2 indicators
Civic scientific literacy	Scientific knowledge	Those scientific knowledge which should be and can be mastered by ordinary citizens in daily life	Scientific concept	Basic terms in science lectures, like electron, DNA; scientific terms frequently used in hot spots of public opinion or the mass media, like influenza A(H1N1), SARS
			Scientific judgment	Judgment on scientific facts and principles, on scientific organizations or scientists
			Understanding scientific research	Understanding process of scientific research, including basic, applied and development research; understanding methods of scientific research
	Scientific awareness	Citizens' cognitive levels for understanding nature and value of science and technology in daily life, work and learning, as well as behavior intention based on science awareness	Nature of science	Understanding boundary between science and superstition; understanding boundary between pursuit of science and blind worship for science; behavior preference based on scientific knowledge
			Science technology and society	Understanding Chinese version of sustainable development; understanding significance of scientific research in the aspect of economy and productivity, social progress and harmony, resources and environment
Civic scientific literacy	Scientific capability	Ability to utilize scientific knowledge and methods to solve problems, deal with affairs, as well as ability of initial exploration and innovation	Ability to deal with practical affairs	Ability to find and ascertain problems; ability to collect and use evidence; ability to reach and explain conclusions; ability to make use of scientific knowledge in practice
			Ability to deal with public affairs	Ability to participate in, disseminate, and organize public affairs
			Innovation ability	Ability to understand scientific information and judge scientific facts; ability to inquire into connections between objects; ability to predict the changes of affairs; ability to reflect independently; ability to question authoritative conclusions with evidence

Indicator system application suggestions include: using a questionnaire that includes two sets of questions, so as to collect sufficient information on the civic scientific literacy.

In the design process, an indicator system applicable to the whole public should be adopted. Meanwhile, more specific systems that focus on peculiar social groups and special purposes should be considered and designed accordingly.

The indicator system design and practice should be scientific, faithful, strict and authoritative. Any random change or abuse should be shunned and the survey should be practiced by qualified organizations.

Chapter Four Process Design and Control of Chinese Civic Scientific Literacy Evaluation

Civic scientific literacy survey originated in the United States. In 1990, evaluation method of scientific literacy taking Miller system as a benchmark was introduced into China. Ever since, China Association for Science and Technology has launched eight large-scale Chinese civic scientific literacy surveys. Chinese civic scientific literacy observation network was set up in 2001. Chapter Four consists of three parts: process design and confirmatory application of Chinese civic scientific literacy evaluation, choice of survey methods of Chinese civic scientific literacy evaluation, and process control of Chinese civic scientific literacy survey.

Process design and confirmatory application

It is a very complicated and arduous project to construct a new indicator system of civic scientific literacy evaluation, which is certain to experience an evolutionary and constant process with dynamic development. As a result, we carried out a series of demonstration researches aimed at different scales and types in different stages in order to testify whether the new indicator system and evaluation questionnaire are scientific and adaptable. And corresponding adjustments have been made to improve our newly constructed evaluation indicator system and method. The whole process can be divided into three phases (Chart 4-1): theoretical research and construction, initial confirmatory application, and follow-up confirmatory application. In the phase of initial confirmatory application, three demonstration researches have been designed and implemented, one in City H in central part, the other in Province A, and another in the

eastern, central and western parts in China.

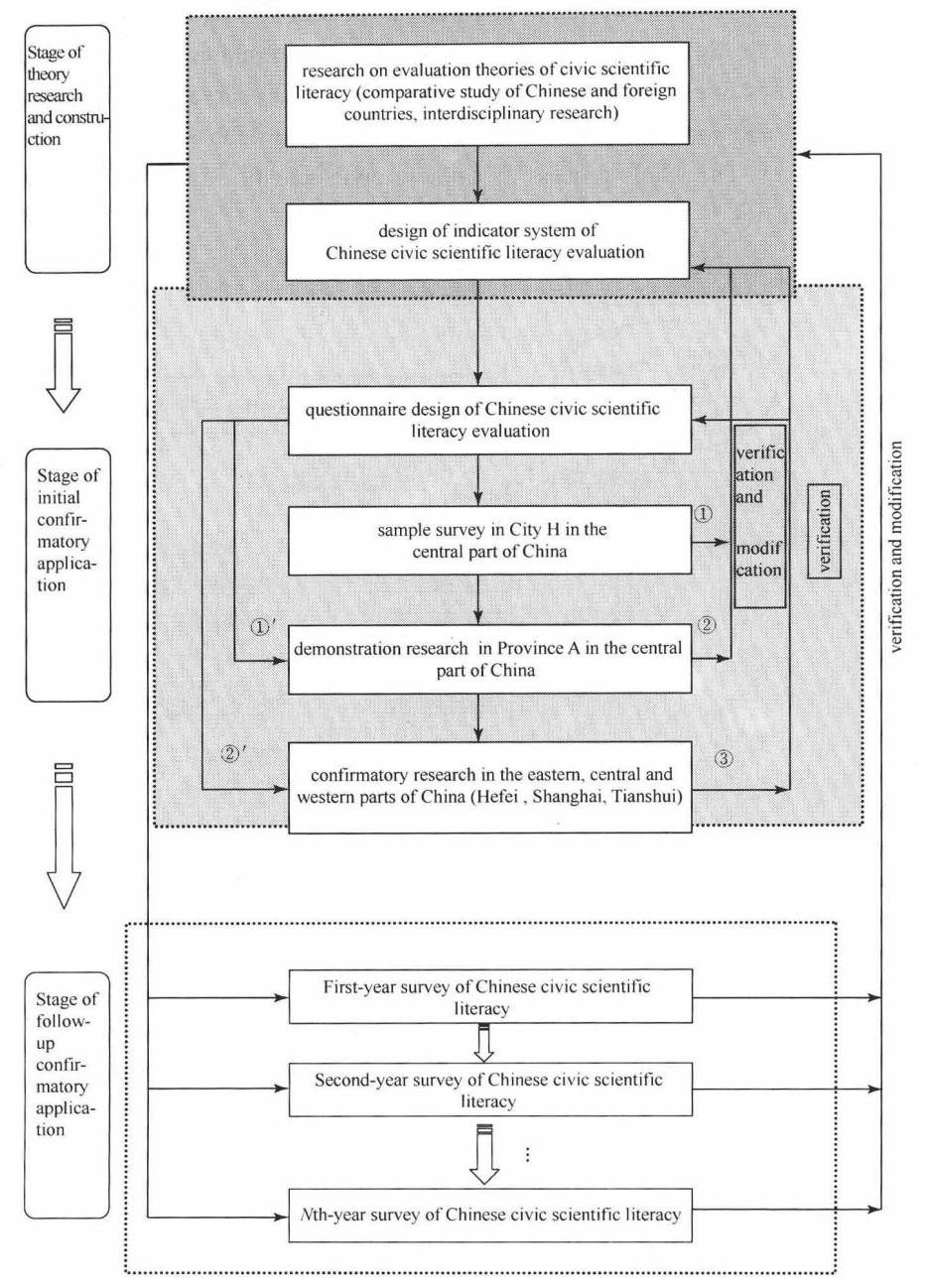


Chart 4-1 Confirmatory Application of Evaluation Indicator System of Chinese Civic Scientific Literacy

①′the questionnaire after the first modification; ②′the questionnaire after the second modification

Annual Chinese civic scientific literacy evaluation is composed of two stages: theoretical research and demonstration research. In the second stage, inquiry into Chinese civic scientific literacy is implemented. In general, questionnaire design and adjustment composes one or several small sample experimental survey, which makes it possible to find and correct improper items in the initial questionnaire before a formal, large-scale survey. The whole process of Chinese civic scientific literacy evaluation is indicated in Chart 4-2.

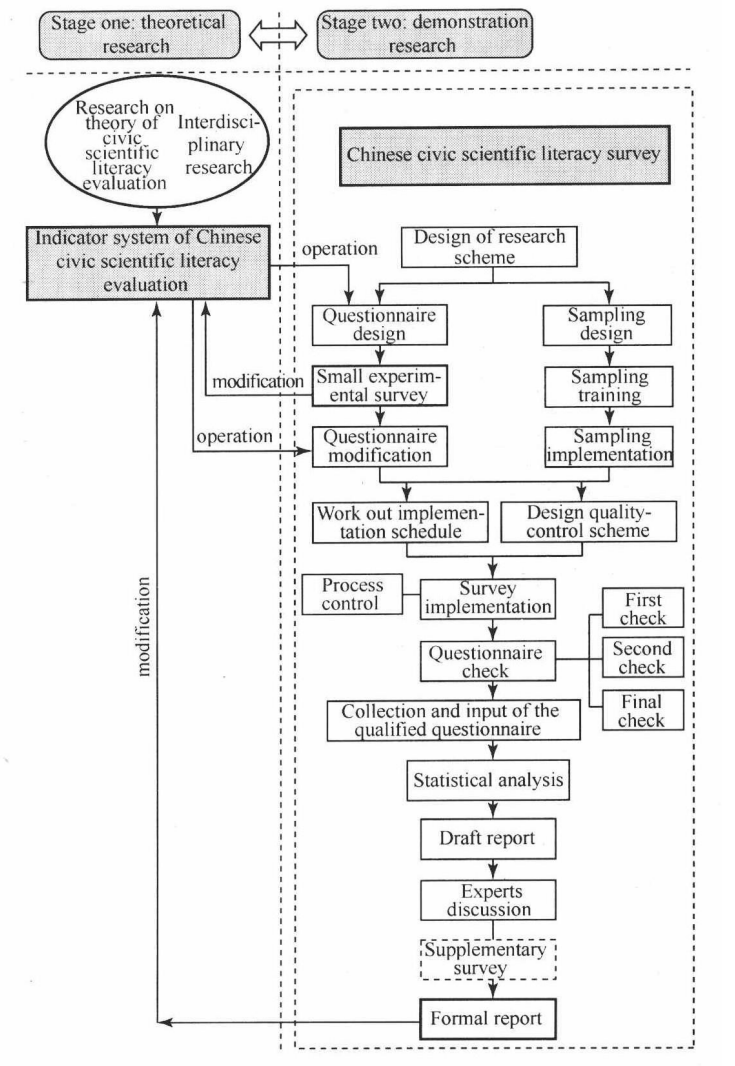
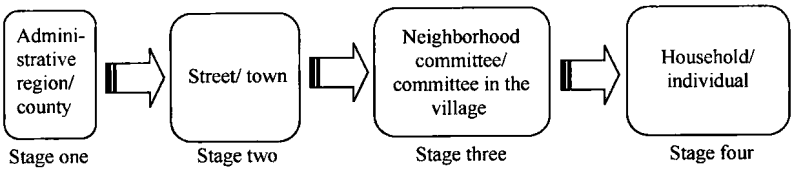


Chart 4-2 Process of Chinese Civic Scientific Literacy Evaluation

The choice of survey methods

Four-stage stratified PPS sampling has been employed in Chinese civic scientific literacy survey.



Stage one: administrative region (urban and suburban areas in prefecture-level city, capital city and municipality) and county (including county-level city) as level-1 sampling unit.

Stage two: street and town as level-2 sampling unit.

Stage three: neighborhood committee and committee in the village as level-3 sampling unit.

Stage four: household as level-4 (final) sampling unit. One person is determined in one household.

Following scientific sampling principles, this sampling method conforms to present situation in China.

In actual sampling, a series of problems such as obsolescence of household registration materials and sampling frame, lag or lack of census data on population, low level of informationization databases of population, will bring difficulties to sampling of social survey. Focus and proper solution is thus called for to ensure samples' quality.

Taking following particular factors in China into consideration, household face-to-face interview survey methodology is preferred in the formal civic scientific literacy survey.

Uneven regional development. China has a vast territory, and there are uneven developments in the eastern and western parts. Great difference also exists in popularity of technological equipment such as telephone or internet.

Deficiency in the survey atmosphere in the real world. Compared with America, China has a shorter history in telephone survey. There is no good warm atmosphere in the public, for most people hold a negative attitude towards phone survey.

Wide individual variety and complexity of survey. China has the largest population in the world, with vast differences in education level in individuals. Population engaged in agriculture accounts for a large percentage, while poor illiterates or semi-lit-

erates account for a certain percentage.

Thus, in China, face-to-face survey methodology is preferred in civic scientific literacy survey. The popular, frequently used random digit dialing telephone survey does not fit in.

Process control

A successful survey depends on careful and effective implementation of every link: design—preparations—sampling—implementation of field survey—questionnaire collection. It calls for strict management and control during the whole process of survey. In the demonstration research, we set up unified action mechanism helpful to better survey implementation process (Chart 4-3). In addition, process management protection system contributing to ensure and improve survey quality was established as well.

As a systematic and complicated project, national survey of Chinese civic scientific literacy involves lots of unpredictable and uncontrollable factors. Considering the fact that widespread samples may increase difficulty in implementation of household face-to-face survey, we set up effective unified action mechanism so as to realize decomposition and management of the task at different levels, finish complex sampling work, and forward the implementation of project.

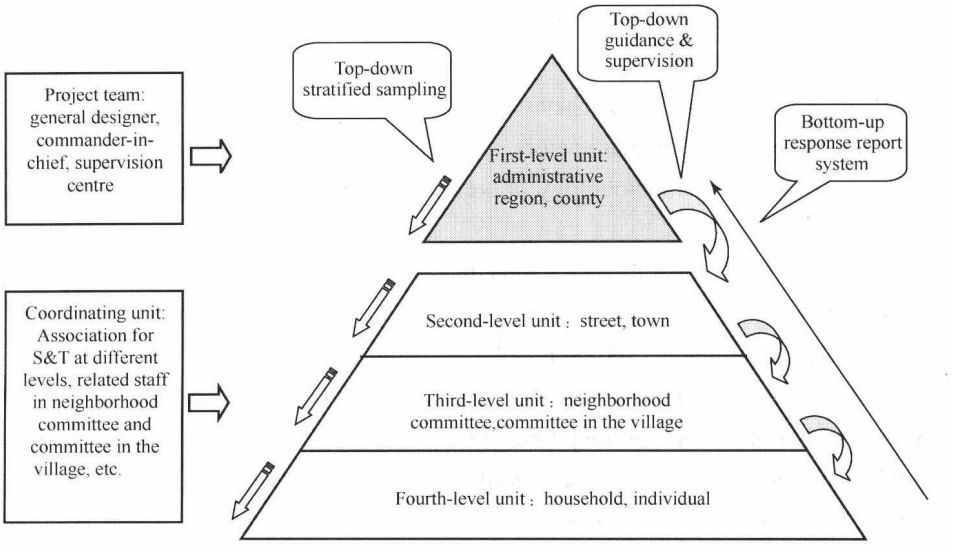


Chart 4-3 Stratified Group and Management of Sampling of Survey on Chinese Civic Scientific Literacy

In order to ensure efficiency and quality of implementation, we put forward and enforced a series of process control measures, such as strict investigator selection system, investigator training system, supervisor system, item-by-item inspection system, multi-level report system, and return visit system, and so on (Chart 4-4).

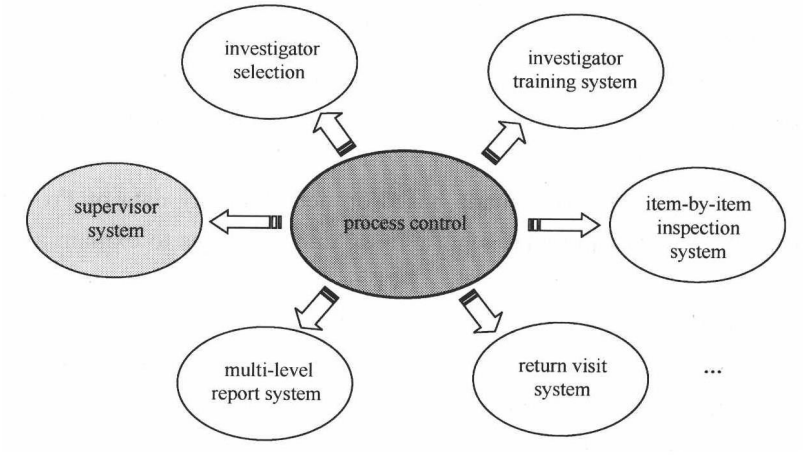


Chart 4-4 Protection System for Survey Process Control

Chapter Five Test and Evaluation Methods of Civic Scientific Literacy

In Chapter Five, comparison analysis has been made on Classical Test Theory (CTT) and Item Response Theory (IRT), esp. strong and weak points in testing civic scientific literacy.

Classical Test Theory

In this part, explanation is made on many links concerning CTT, such as parameters and methods of questionnaire construction and test, project analysis, reliability and validity test, exploratory factor analysis, and so on. There is an introduction on how to make use of CTT to measure scientific literacy. Besides, CTT's existing problems and puzzles in testing scientific literacy are discussed.

Item Response Theory

In this part, there is a brief introduction to the history and development of IRT,