Invited Plenary talk

Compare of SCIENCE STUDIES Theory System in China and Foreign Countries Based on Scientometrics

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Abstract

During the last 10 years, a new framework of SCIENCE STUDIES Theory System has been formed with the progress of science and technology (S&T). Starting with the research tradition and paradigm, we study the main academic fields, the relative disciplines and focuses of SCIENCE STUDIES with the analytical tools and the methods in Scientometrics. The results of study conclude the following:

- in the applied field, "Science", "Technology", "Innovation" and corresponding "S&T Policy and Management" are found in the mainstream;
- in the methodological field, "Webometrics", "Knowledge Mapping and Visualization Technology", which are the advanced domains, have developed greatly;
- in the theoretical field, scholars and scientists start to focus on the interaction of Science-Technology-Innovation, the evolution of some disciplines in natural science and the theory of cooperation in S&T.

Basing on the above, the construction of SCIENCE STUDIES Theory System in the new century is discussed.

1. Introduction

Since the date of publication of THE SOCIAL FUNCTION OF SCIENCE (J.D.Bernal,1939)[1], SCIENCE STUDIES has been developed for 66 years. In China, since the date of publication of MODERN SCIENCE AND TECHNOLOGY (Qian Xuesen, 1977) [2], SCIENCE STUDIES has been developed for 28 years. During this long time of development, though the theory system and disciplinary position of SCIENCE STUDIES are constantly challenged by other relative disciplines, as a cross-science, it is still absorbing various disciplinary knowledge and develops vigorously.

The development of a discipline depends on the demand from society. Similarly, the maturity of a theory system for a discipline also depends on the satisfaction to meet the society demand. Meanwhile, the position of this discipline will be established. Based on the above theory, we study the evolution of SCIENCE STUDIES in China and the world in the past 10 years using the analytical tools and methods in Scientometrics, starting with the research tradition and paradigm, and then discuss the construction of the SCIENCE STUDIES Theory System.

General paradigm of the Construction of SCIENCE STUDIES Theory System

The paradigm of SCIENCE STUDIES has been formed since the publication of THE SOCIAL FUNCTION OF SCIENCE, which includes two problem-solving activities, namely the human-to-human activity and the human-to-nature-generated S&T activity. Initially, studying the integration of natural science, humanity science and social science, the integration of naturalism, humanitarianism and communism was put forward in Karl Marx's ECONOMIC AND PHILOSOPHICAL MANUSCRIPTS, and later the general paradigm, advanced by Marx, correlates the mutual relationship between production and relations of production with historical materialism as a line to analyse human history and all social phenomena. Qian Xuesen supported Marx' paradigm on SCIENCE STUDIES and further advanced that Science Ability Studies, Political Science Studies and System Science of S&T should constitute the SCIENCE STUDIES Theory System[3]. Later, Feng Zhijun advised to substitute "Political Science Studies" by "Institutional Science Studies"[4]. Zhao Hongzhou believed that Scientometrics was a basic branch of SCIENCE STUDIES, and SCIENCE STUDIES was rooted in Scientometrics, and therefore, SCIENCE STUDIES should be Scientometrics. Based on the above, we generalize four basic branches of SCIENCE STUDIES Theory System[4] as outlined below:

Science Ability Studies——Study on S&T activity and the rule and ability of human to realize and practice nature on the level of human-to-nature.

Institutional Science Studies——Study on the interaction of policy-economy-society-culture-nature-S&T,on the level of human-to-human, S&T is taken as one of factors in social science.

Science System Studies——Study on the science results, which are "knowledge system of S&T" and "disciplinary structure" oriented from interaction between S&T production and S&T production relations.

Scientometrics——Study on S&T activity and S&T development with quantitative analysis methods.

In terms of the difference in theoretical and applied aspects, all branches and marginal disciplines (excluding General Science Studies) can be divided into 3 parts, namely Theoretical SCIENCE STUDIES, Special SCIENCE STUDIES and Applied SCIENCE STUDIES. There is seem no clear borderline between SCIENCE STUDIES Theory System and other independent comparatively, such as History of Science, Philosophy of Science, Sociology of Science and Economics.

There is also a debate on the research object of SCIENCE STUDIES. Is it only science activity or the whole S&T activity? There is a suggestion to extend SCIENCE STUDIES to "S&T Studies" at all times due to SCIENCE STUDIES is always misunderstood as focusing only on Natural Science[5,6]. However, Bernal, the founder of SCIENCE STUDIES, praised highly on the advancement of D. Price, the father of Scientometrics, which is "SCIENCE STUDIES" or "SCIENCE of SCIENCE" can be called 'history, philosophy, sociology, psychology, economics, politics, operation, etc. for science, technology and medicine'[7,8]. Actually, the research of SCIENCE STUDIES and Scientometrics has never been limited in Natural Science, but opened to a broader knowledge of S&T.

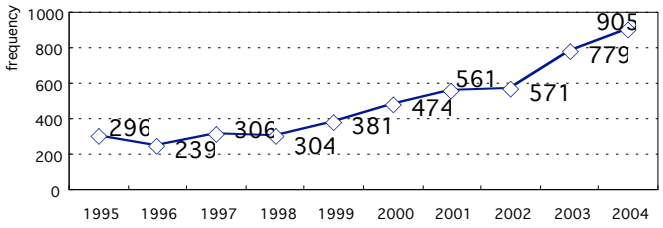
We tend to neglect the basic disciplinary system of SCIENCE STUDIES, and divide the Theory System of SCIENCE STUDIES into theoretical research, applied research and methodological research.

2. SCIENCE STUDIES Theory System in China

In order to study on the Chinese SCIENCE STUDIES Theory System, ten core journals on SCIENCE STUDIES are selected in our research as data source, which are *Science Studies, Science Research Management, Science of Science and Management of S.&T., Research and Development Management, Forum on Science and Technology in China, Studies in Dialectics of Nature, and S&T and Dialectic, Science and Technology Management Research, Scientific Management Research, and Science & Technology Progress and Policy*. We conduct words frequency analysis to the words appeared in abstracts and keywords in these ten journals retrieved from Chinese Journals Fulltext Database(CJFD), according to 100 keywords representing theoretical research, applied research and methodological research in SCIENCE STUDIES, which are given by scholars.

Seen from the whole, the keywords frequency increased during the period of 1995 to 2004 (Fig.1), which means increasing science productivity and broader academic impact of SCIENCE STUDIES.

Fig.1 Increase trend of keywords frequency in SCIENCE STUDIES(1995-2004)



However, the research activity appears evident imbalance in main domains of SCIENCE STUDIES. In these 10 years, the research in applied field, such as S&T policy, Strategy, Management, Institution, is most active and accounts for 71% of total research, and among which S&T institution only accounts for 13%. The research in theoretical and methodological fields is less active, accounts for only 29%,(Fig.2) It shows that SCIENCE STUDIES is still on the qualitative describe level in China, and lack in theoretical, quantitative and institutional research.

The percentage of research in theoretical, applied and methodological fields change from 27%:64%:9% in 1995 to 12%:63%:25% in 2004 respectively. It means that applied research is dominant and most active on SCIENCE STUDIES at all times, theoretical research decreases greatly

while methodological research increases greatly. More attentions should be paid to these different development trends.

Fig. 2: The distribution of relative topic frequency

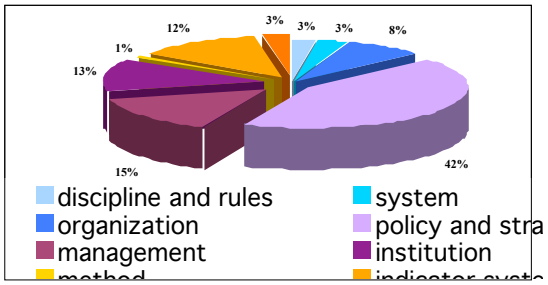
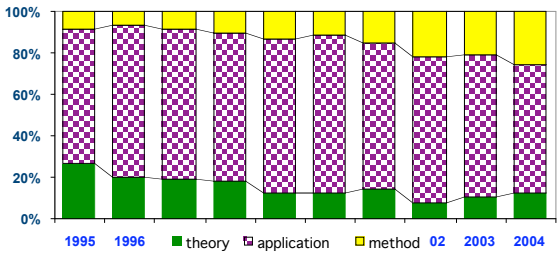


Fig. 3 Words frequency distribution in 3 fields



In general, applied research has been dominant in the recent ten years all along. It shows the good tradition that research on SCIENCE STUDIES faces to practical problem, such as "S&T progress" and "technology innovation policy, strategy, management". It also shows the high quality results in applied research is limited by lacking well-nit theoretical and methodological supporting, and appears weak in applied research. At present, Chinese SCIENCE STUDIES is faced with theoretical crises and challenge, and it is significance in practical aspect and strategic aspect to strengthen study in SCIENCE STUDIES.

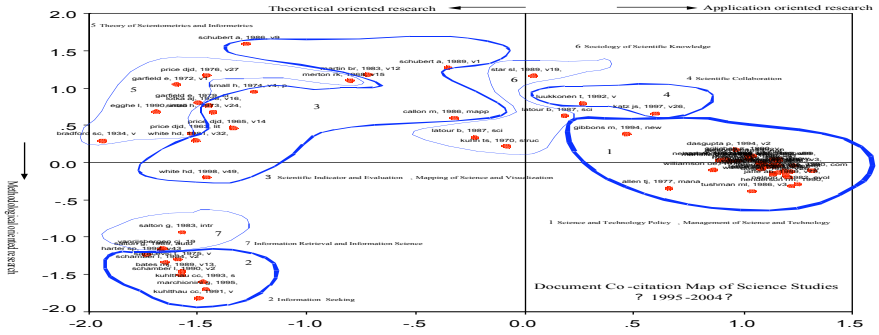
3. *SCIENCE STUDIES Theory System in the world*

In order to learn about the progress in international SCIENCE STUDIES, the data oriented from 4800 papers , and acquire 126244 citations in 6 high impact journals(*Social Studies of Science, Science Technology & Human Values, Scientometrics, Journal of the American Society for Information Science and Technology, Research Policy, and R & D Management.* in SCIENCE STUDIES) were retrieved from SCI(1995-2004). We use Citation analysis, MDS-multidimensional scaling, Factor Analysis (PCA), Cluster analysis and Co-word analysis methods[9,10,11], applied knowledge mapping and information visualization technology[12,13,14] to deal with the data and describe the activities in SCIENCE STUDIES.

3.1. *Main domains and evolution in SCIENE STUDIES.*

We conduct multi-scaling analysis and cluster analysis to 70 most frequently cited document, and draw a co-citation mapping to show the main domains in SCIENE STUDIES(Fig.4). 7 knowledge clusters (main domains)were emerged ordinal by density : *1. S&T policy and management;2. Information seeking technology;3., scientific indicator, mapping of science and visualization;4. collaboration in S&T;5. Scientometrics and Informetrics;6. Sociology of scientific knowledge;7. Information retrieval technology and information science.* Their relationship is reflected by the position and distance. We can understand it to be a double-directed pattern, one hand, the applied field in SCIENCE STUDIES(Cluster1,4)leads the theoretical field (Cluster 6,3,5) and methodological field (Cluster 2,7), (1_4)_(6_3_5)_(7_2), on the other hand, applied field(Cluster1,4) and methodological field (Cluster 2,7) are extended from the core, theoretical field (Cluster 6,3,5), (1_4)_(6_3_5)_(7_2).

Fig. 4: Document co-citation map of SCIENCE STUDIES.



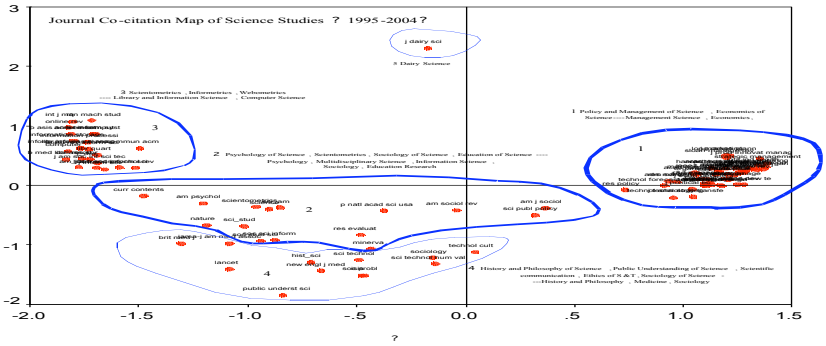
The result of PCA(Prominent Component Analysis) to these 70 document is similar. 6 main components is listed in Tab.1, they accordant with the main domains in knowledge mapping. More important, Fig.1 shows the evolution trend of main domains in SCIENCE STUDIES.

These trends are confirmed by the papers submitted in "10th International Conference of the International Society for Scientometrics and Informetrics"[16]. 44 papers concerns about methodological research with topic on "Webometrics", "Informetrics", "Mapping of science and visualization", "Citation analysis", "Information retrieval", and counts for more than a half. 20 papers concerning about theoretical research with topic on "Development of S&T" and "Evolution of discipline". 11 papers concerns on applied research with topic on "Performance evaluation", "National scientific indicator". Additionally, 19 papers concerns about "Collaboration inS&T".

Modern SCIENCE STUDIES and relative disciplines.

As an interdiscipline, SCIENCE STUDIES is always crossed with other disciplines. 100 most frequently cited journals are conducted by co-citation analysis, MDS analysis and cluster analysis, and do a journal co-citation mapping(Fig.5). Generally, a special journal can represent a discipline field, so the journal co-citation mapping is equal to a relative disciplines mapping. Seen from Fig.5, 4 discipline clusters are formed by journal co-citation cluster analysis. Cluster 1 includs Management Science and Economics ,and closes nearly to the branches of applied field, "S&T policy and management" and "Economics of science". Cluster 2 concerns about Psychology, Multidisciplinary Science, Information Science, Sociology and Education Science, and is crossed and superposed by the branches of theoretical field, "Psychology of science", "Scientometrics", "Sociology of science" and "Scientific education". Cluster 3 concerns Library and Information Science, Computer Science, and is overlapped with methodological branches, such as "Scientometrics", "Informetrics" and "Webometrics". Cluster 4 mainly concerns on History of Philosophy, Medicine and Sociology, and it crosses with "History of science", "Philosophy of science", "Public science", "Ethics of S&T" and "Sociology of science".

Fig. 5: SCIENCE STUDIES and relative disciplines mapping (1994-2004).



Cluster 2 being characterized by interdisciplinary mostly closes to all other 3 clusters, like a bridge. It provides theory foundation to applied field (cluster 1) and theory support to methodological field (cluster 3). Make PCA to 100 highly cited journals, list top 3 principle components, which accounts for 79.107% cumulative contribution, we found the result is similar to journal co-citation analysis(Tab.2). Factor 1 corresponds to Cluster 1, Factor 3 corresponds to Cluster 4, Factor 2 corresponds to the integration of Cluster 2 and 3.

Tab. 2: Relationship between SCIENCE STUDIES and relative disciplines by PCA.

Facors	1	2	3
Initial Eigenvalues	40.194	27.345	11.568
% of Variance	40.194	27.345	11.568
Cumulative, %	40.194	67.539	79.107
Relative disciplines	Management, Economics, Finance	Psychology, Interdiscipline, Library and information science, Sociology, Medicine, Computer science	History and philosophy, Medicine, Sociology, Ethics
Branches of SCIENCE STUDIES	S&T policy and management, Economics of S&T	Psychology of science, Scientometrics, Informetrics, Webometrics, Sociology of science, Ethics of S&T	History and philosophy of science, Public understanding of science, Scientific Communication, Sociology of science, Ethics of S&T
Research Fields in SCIENCE STUDIES	Applied research	Theoretical and methodological research	History and Philosophy research on science, Relationship between science, technology and sociology

The analysis above shows the main domains, the frontiers, branches and relative disciplines in SCIENCE STUDIES according to the theory, application and method, a new frame of SCIENCE STUDIES Theory is forming primarily.

4. Compare of SCIENCE STUDIES Theory System in China and the world.

We compared the research object in China with the world basing on the above, and found some interesting results by word frequency analysis and co-word analysis to 7 Chinese journals and 6 international journals in SCIENCE STUDIES[17,18].

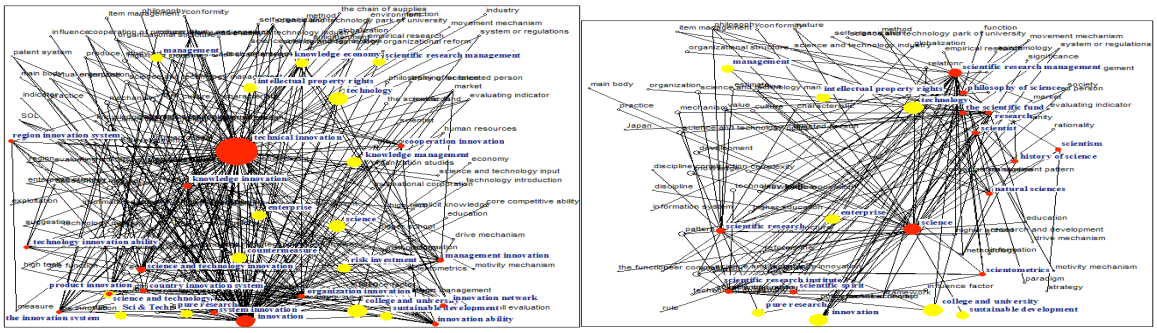
Seen from Tab.3, there shows 5 common key words (“Science”, “Technology”, “Innovation”, “Knowledge” and “Firm”) in Chian and overseas, and same in top 3 words except the order, it means “Science”, “Technology”, and “Innovation” are general and longtime topics in SCIENCE STUDIES. “Innovation” is a hot topic especially in SCIENCE STUDIES field in China, the research on it is more deeply, meanwhile, the concept of innovation is more broader (Fig.6).

Tab. 3: The top 10 high frequency keywords in China and the world(1995-2004)

	1	2	3	4	5	6	7	8	9	10
China	__innovation (452)	__ Technology (200)	__ Science (178)	__ University (129)	__ Policy (102)	____ Knowledge management (94)	__ Enterprise (90)	____ Property right (83)	____ Insurance investment (80)	____knowledge economy (80)
Overseas	Science (282)	Innovation (219)	Technology (178)	Knowledge (114)	Performance (99)	firm (91)	Model (85)	__indicator (84)	__information (75)	__ retrieval (65)

Fig. 6: Co-word network of keywords characterized by innovation and non-innovation in Chinese journal

Fig.7 Co-word network of keywords oriented from Chinese journals characterized by science and non-sciences



__ Keywords characterized by innovation

__ Keywords characterized by non-innovation

__ Keywords oriented from journals characterized by science

__ Keywords oriented from journals characterized by non-science

Fig.6

- It is a co-word network of 200 high frequency keywords and keywords characterized innovation oriented from 7 Chinese journals in SCIENCE STUDIES. Two knowledge clusters with the core of “technology innovation” and “innovation” is appeared, and in which the knowledge cells(keywords) have common characters: (1) with an affinity for the keywords characterized innovation, such as “innovation system”, “institution innovation”, “organization innovation”, etc. ;(2) with a extensive co-currency with general keywords without innovation character; (3) only few relation with high frequency non-innovation character keywords, such as “science”, “basic research”, “university”, etc. even no contact.
- This means Chinese scholars treat innovation and technology innovation in the same sense, and little from the viewpoint of integration of science- technology-innovation to study SCIENCE STUDIES.

Fig.7

- It is a co-word network of 200 high frequency keywords and science-characterized keywords. Some knowledge cells, “scientist”, “science research”, “research management”, etc., constitute knowledge cluster cored by “science”, which co-occur with non-science-characterized keywords, but little with non-science-characterized core keywords, “technology innovation” is disappeared from this mapping. However, it is surprised that the knowledge cluster and its knowledge cells are very close to the word, “innovation”.
- This means there is different understand to “innovation” between the research objected by science, such as “Philosophy of science” and “Technology innovation”. It is also to say that there really exist the separation between science and technology, technology innovation on research of science activity and technology innovation in China.

Fig.8 Co-word network of high frequency keywords oriented from international journals in SCIENCE STUDIES

Fig.9 core cluster and sub-clusters in co-word network of international SCIENCE STUDIES

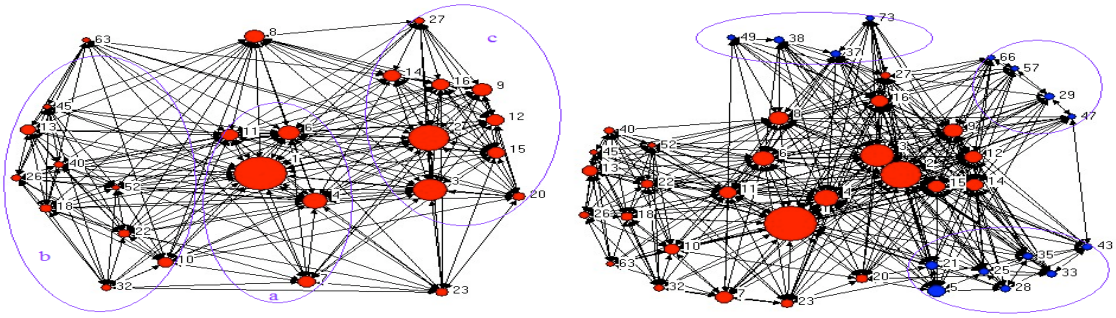


Fig.8

- It is a co-word network (k=12, means closed contact network) of 100 high frequency keywords oriented from 6 international journal in SCIENCE STUDIES. 3 knowledge clusters emerge in the network, cluster a(*Science(1), Knowledge(4), Information(7), System(11), etc.*), cluster b(*Retrieval(10), Information retrieval(13), World Wide Web(32), Users(45), Behavior(22), etc.*), cluster c(*Innovation(2), Technology(3), Firms(9), Network(12), Industry(14), Research-and-development(15), Management(16), etc.*).
- Cluster a contact closely with cluster b and c respectively, *Science(1)*, the core of cluster a, co-occurred closely with *Innovation(2)* and *Technology(3)* , which are the core of cluster b. *Science*, *Technology* and *Innovation* is integrated into a core knowledge cluster in modern SCIENCE STUDIES. This means the research object in SCIENCE STUDIES not only extend from science to technology and innovation, but also to the integration. Cluster b supports cluster a and b through its cells and *Information(7)*, *Model(8)* and *Communication(23)*, etc. and become an important field assisting to theoretical and applied research in SCIENCE STUDIES. It should be noted that *Knowledge(4)* at the middle position among *Scienc*, *Innovatio* and *Technology* plays a role liking bridge. This means science, innovation and technology mutual impact through knowledge. For instant, keywords are taken as knowledge cell in word frequency analysis and co-word analysis, S&T activity is taken as knowledge cell in Webometrics, Informetrics and Scientometrics, in this sense, scientometrics and relative measure disciplines should unified knowmetric, which take knowledge cell as measure object.

Fig.9

- It is a co-word network(k=11), and shows the relationship between cluster c(cored by *Science*, *Innovation* and *Technology*) and 3 sub-clusters. Cluster d(*Perspective(37),Firm(38),Product(49), Capabilities(73),etc.*) Cluster e(*United-States(29), Competition(47), Globalization(57), Internationalization(66),etc.*) Cluster f (*Collaboration(21),Cooperation(33), Indicator(5), Growth(25), Policy(28), Bio-technology(35), Spillovers(43), etc.*). That means, the research object of SCIENCE STUDIES is extended from the core topic(science, technology and innovation) to three fields extensively and deeply, which are :(1) technology innovation promote production growth, core ability and develop perspective of firm from the viewpoint of SCIENCE STUDIES; (2) technology innovation impact to United States, international relationship and competition ability on the background of globalization; (3) the relationship of technology innovation with collaboration in science and technology, technology cooperation, knowledge spillovers, bio-technology and corresponding policy.

6. Conclusion.

---- It is appropriate to divide SCIENCE STUDIES Theory System into three mutual filter and mutual different parts, theoretical research, applied research and methodological research, not overemphasize the margin of disciplines.

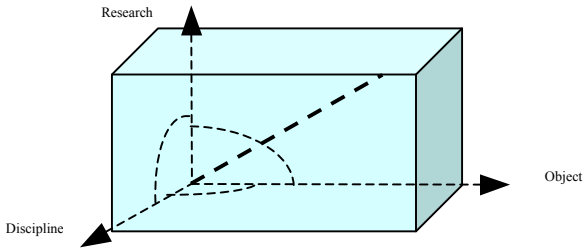
----Prior to conduct applied research on S&T policy and management, emphasis on the integration of science, technology and innovation.

----The research in china is behind overseas. Webometrics, mapping of science and visualization starting in the 1890s in the world, but which arise in China just now; the upsurge of S&T indicator and evaluation has gone in the world , but in China, it come to us gradually; SSK decreased in the world in last century, but it is a academic focus in new century in China.

5. *Thinking about Science Studies theory system and discipline development in new century*

Basing on the comparative analysis of China and foreign countries, we acquired some ideas on the construction of SCIENCE STUDIES Theory System, the aim is not limited to reflect and generalize the present of SCIENCE STUDIES, but to supply an idea and a frame for studying on the activity of science and technology in general, reveal the rules of modern S&T activity, and offer advices to macro-decision and practice.

Fig. 10: Basic framwork of SCIENCE STUDIES Theory System



Tab.4: "Research-Object" two dimension structure

	Object: Science, Technology, Innovation and the relationship of science- technology-innovation and economy-society-nature		
Theoretical	**Disciplines and rules:** Science ability studies, Institutional science studies, Sociology of science, Development rules and model of S&T	**Knowledge system:** Knowledge system of S&T, Classification and structure of science S&T, R&D system	**Scientific research organization:** Scientific community, Scientific institution, S&T college, Academic teamwork, Alliance, Collaboration in S&T, S&T agency
Applied	**Policy and strategy:** Policy and strategy of S&T, Technology innovation policy, Input of S&T, Person with ability and encouragement policy	**S&T system:** S&T system, S&T restructuring, institutional innovation, Intellectual property right system, S&T lawmaking	**S&T management:** Management of S&T, Scientific research management, Enterprise technology innovation, Innovation management, R&D management, Management ,Knowledge management
Methodological	**Metrology:** Scientometrics, Informetrics, Biblometrics, Webometrics, Knowledge mapping and visualization	**Evaluation indicator:** S&T evaluation indicator system, Research performance evaluation, S&T ability evaluation, Science review, Technology evaluation	**Model method:** Scientific research model, Evaluation model, Predict model, Predict of S&T, forecast of S&T

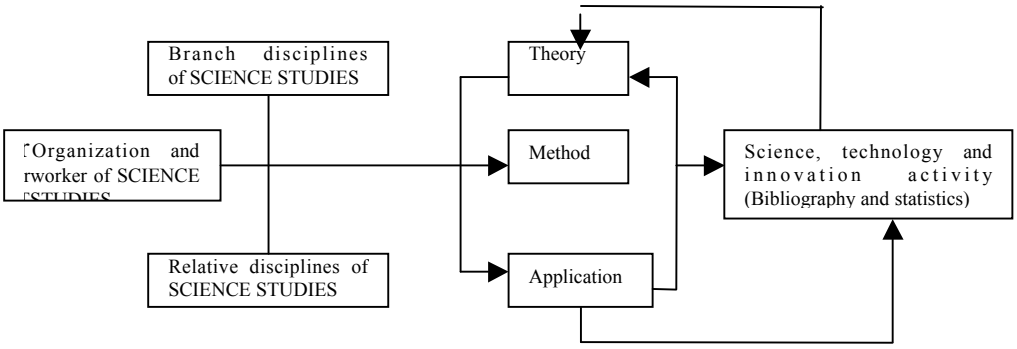
Tab. 5. "Research-Discipline" two dimension structure

Research fields	Applied	Theoretical and methodological	Multi-disciplinary research (history, philosophy, sociology)
Branches	Policy and management of S&T, Economics of S&T, Laws of S&T	Scientometrics, Informetrics, Webometrics, Sociology of science, Psychology of science, Ethics of S&T	History of science and philosophy of science, Popularization and broadcasting of science, STS, Sociology of science
Relative disciplines	Management, Economics, Politics, Laws	Mathematics, Computer science, Information science, Library and information science, Sociology, Medicine, Psychology	History and philosophy, Medicine, Sociology, Ethics

Tab. 6: "Basic discipline-Research field"two dimension structure

	Theoretical	**Applied**	**Methodological**
Science Ability Studies	**Scientific research productivity** Development rules of science, technology and innovation, study on S&T activity, study on S&T ability, study on technology innovation	**Scientific research system engineering** Ability of science and technology, ability of R&D, S&T ability of nation and enterprise, technology innovation ability, national S&T competitive strength	**S&T indicator and evaluation** Evaluation of S&T ability, evaluation of national S&T competitive strength, system analysis, indicator system, evaluation model
Institutional Science Studies	**Relationship between scientific research and production** Mutual action between S&T and society, social function of S&T, institutional factor, social processing and social results of S&T development	**Social organizational system S&T system** Scientific research organization, S&T policy and strategy, S&T management, industry-university-institution collaboration, technology alliance, national innovation system	**Historical material theory method** Statistical analysis of S&T and society, measure of institution factor in S&T development, S&T assist decision system
Science System Studies	**Knowledge system of S&T** Knowledge system of S&T,disciplinary differentiation,intercross,and evoluation rules, science classification and structure theory, technology system and structure, science theory system	**S&T forcasting** The frontier discipline of science, growth point of new discipline, the application in education special classification and library classification	**Science classification method** The application of scientometrics in S&T system, S&T forcasting method, the cluster analyusis of science knowledge cluster and disciplinary cluster
Scientometrics	**Foundation of scientometrics theory** Mathematics, informationtheory, the relationship between webometrics, informetrics and scientometrics	**The measure of science, technology, innovation and mutual relationship between them** The application of web-information technology in scientometrics, S&T database	**Measure approach and method in scientometrics** Knowledge mapping and information visualization thchnology, knowledge database, information retrieve technology

Fig. 15: Science Studies theory system: "Discipline- Study- Object" three dimensional dynamical structure



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