Bibliometric-based Study of Scientist Academic Genealogy

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Citation: Lv, R.H., & Chang, H. (2021). Bibliometric-based study of scientist academic genealogy. *Journal of Data and Information Science*, 6(3), 146–163. <https://doi.org/10.2478/jdis-2021-0021>

Received: Dec. 13, 2020

Revised: Feb. 7, 2021;

Mar. 16, 2021

Accepted: Mar. 16, 2021

Abstract

Purpose: This study aims to construct new models and methods of academic genealogy research based on bibliometrics.

Design/methodology/approach: This study proposes an academic influence scale for academic genealogy, and introduces the w index for bibliometric scaling of the academic genealogy. We then construct a two-dimensional (academic fecundity versus academic influence) evaluation system of academic genealogy, and validate it on the academic genealogy of a famous Chinese geologist.

Findings: The two-dimensional evaluation system can characterize the development and evolution of the academic genealogy, compare the academic influences of different genealogies, and evaluate individuals' contributions to the inheritance and evolution of the academic genealogy. Individual academic influence is mainly indicated by the w index (the improved h index), which overcomes the situation of repeated measurements and distortion of results in the academic genealogy.

Practical implications: The two-dimensional evaluation system for the academic genealogy can better demonstrate the reproduction and the academic inheritance ability of a genealogy.

Research limitations: It is not comprehensive to only use the w index to characterize academic influence. It should also include scholars' academic awards and academic part-timers and so on. In future work, we will integrate scholars' academic awards and academic part-timers into the w index for a comprehensive reflection of scholars' individual academic influences.

Originality/value: This study constructs new models and methods of academic genealogy research based on bibliometrics, which improves the quantitative assessment of academic genealogy and enriches its research and evaluation methods.

Keywords Academic genealogy; Evaluation system; Academic influence; Academic fecundity; Liu Tungsheng

1 Introduction

As a new research direction in science history, the scientist's academic genealogy has attracted an increasing share of attention in recent years. In existing studies (Jackson, 2007; Kelley & Sussman, 2007; Li & Xia, 2013; Wuyunqiige, 2009), academic heritage has provided important clues for drawing academic genealogies, elucidating academic heritages, studying the origin and evolution of academic genealogy, and exploring its internal and external causes. Most of these studies borrow the methods of history or science sociology. As is well known, the scientist academic genealogy is a complex system with a long slow process of production, continuation, development, and termination. If one could replace the time-consuming traditional methods with bibliometrics, which focuses on scientists' academic achievements and characterizes the developmental stages of their academic genealogies, one might improve the integrity and efficiency of the academic genealogy evaluation system.

After systematically reviewing the status of scientist academic genealogy, current bibliometric methods, and new tools, this study builds a scientific evaluation system based on the bibliometrics method. This system analyzes a scholar's academic influence and genealogical position from both qualitative and quantitative perspectives.

This study takes the scientist academic genealogy as the research object and uses bibliometrics to construct new models and methods of academic genealogy research. This approach is an important paradigm shift for pioneering, advancing, and innovating search systems, thereby improving academic genealogy research. Moreover, by studying the academic genealogy of scholars, we can establish the basic relationship between the scholar's discipline and related disciplines, restore the historical trajectory of science and technology, establish the inherent laws and evolutions of disciplines, combine the developments of science and technological reality, and predict future developments of disciplines and breakthrough directions. At the same time, studies of scientist groups can reveal the scientific spirit and academic style of the group, identify scientific traditions or promote the formation of scientific traditions, and incubate scientific and innovative cultures for exploring the growth of science and technology talent.

2 Review

A scientist academic genealogy is defined as an academic group composed of different generations of scientists, reflecting the academic and inheritance relations among the main group members. Scientist academic genealogy was pioneered in the mid-twentieth century, when science sociologists noticed a close successional

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relationship between the disciples of many Nobel laureates, and began researching their academic genealogies (Zuckerman, 1979). However, academic genealogy has long remained a relatively small field. An early publication of scientist academic genealogy was Tyler (1992), who constructed a medical academic genealogy starting from the pharmacologist Arthur E. Schwarting, who co-founded the American Society of Pharmacognosy.

The study of academic genealogy gained momentum from 2005, mainly from qualitative perspectives. For example, the Korean scholar Chang Shuirong (2003) constructed the academic genealogy of American physicists and mathematicians throughout the 20th century. Kelley and Sussman (2007) compiled the academic genealogy of primatologists working in primate zoology. They analyzed not only the academic genealogy of the scholars, but also the academic development and interdisciplinary development status of this discipline in the United States and overseas. Wuyunqige (2009) reported a study of scientists' academic genealogy in China. The China Association for Science and Technology established the "Chinese scientists academic genealogy research" project to research the scientist academic genealogies of crucial disciplines. Li and Xia (2013) researched the academic genealogies of rice scientists, and discussed the influence of Yang Kaiqu's academic style and scientific spirit on academic pedigree construction.

The published literature approaches the academic genealogy of scientists from two perspectives: sociological science and history. Scholars adopting the sociology approach use social investigation and literature searching, and construct the academic pedigree from academic heritage lines, considering the academic inheritance between successive generations of scientists. Sociologists of science are mainly concerned with the prestige, distribution mechanism, and incentives of scientists. Meanwhile, historical scholars mainly use the history of scientific thought and the method of scientific social history to study the origin and evolution of academic genealogy, and to explore the internal and external causes of academic pedigree. Historians investigate how academic tradition, cultural connotation, and changing social and political environments influence the development and evolution of academic pedigrees. In recent years, some scholars have departed from the research methods of traditional academic genealogy, and have proposed quantitative analysis methods. For example, Russell and Sugimoto (2009) constructed a quantitative research and evaluation method based on the dissertation or thesis databases. Using the intergenerational number and the number of disciples at each generation, this method evaluates the depth and breadth of academic reproduction. Based on a neural science genealogy database (Neurotre), David and Hayden (2012) formulated a measure of academic genealogy fecundity. Rossi and Mena-Chalco (2015) proposed the genealogical index based on the theory of bibliometrics h-index and examined its main applications. Furthermore, Rossi, Freire, and Mena-Chalco

(2017) set out a formal definition of a metric called “genealogical index”, which can be used to measure the effect of researchers on several generations of scientists. Sanyal et al. (2020) proposed g_m -index, a new mentorship index for researchers, which is based on the theory of bibliometrics g-index. It is an improvement of Rossi’s “genealogical index”. However, the “genealogical index” and g_m -index are indexes of academic metrics of mentors or genealogy, it means an improved index for genealogy fecundity, not an index of academic influence forces.

To our best knowledge, until present, there is no evaluation system that can comprehensively evaluate the academic pedigree from academic reproduction and academic influence. Previously, we found a significantly higher intensity in cooperation within an academic genealogy than cooperation among members in different genealogies (Chang, Lv, & Zhang, 2016). Based on the bibliometrics W-index, (Lv & Chang, 2017) formulated a measure of academic influence of genealogy, which can be used to find the key individual and evaluate the contribution of mentors. Therefore, the first two articles (David & Hayden, 2012; Russell & Sugimoto, 2009) attempted a quantitative assessment of the reproduction ability of academic genealogy, and the last three articles (Lv & Chang, 2017; Rossi, Freire, & Mena-Chalco, 2017; Rossi & Mena-Chalco, 2015) focused on the academic mentoring metrics of mentors and academic influence forces. However, both fecundity and academic influence are all important features of academic genealogy, so the present study attempts to construct a comprehensive evolution system to characterize an academic genealogy.

3 Methods

How can we characterize an academic genealogy by a quantitative method? Academic genealogy fecundity is recognized as an important determiner of a genealogy’s development and evolution. An academic genealogy can become world-famous not only by embracing many members, but also by cultivating famous scientists. For example, Tang Aoqing’s academic genealogy is famous for its eight prominent disciples. Therefore, the numbers of famous scientists and the degree of fame in the academic genealogy are both important characters. To evaluate whether a scientist or an academic genealogy is famous, we propose the academic influence forces, an indicator of academic level. In the following subsections, we employ the academic fecundity and academic influence as the two dimensions in a system for evaluating academic genealogies.

3.1 Academic genealogy fecundity

The academic genealogy fecundity is the basic guarantee that an academic genealogy will develop. The intrinsic motivation of academic genealogy reproduction

has been variously reported as personal character, scientific spirit, and discipline development (Kelley & Sussman, 2007; Li & Xia, 2013; Wuyunqige, 2009). Besides constructing a genealogy chart of intuitive expression, Russell and Sugimoto (2009) and David and Hayden (2012) developed quantitative indices for characterizing academic genealogy. Russell and Sugimoto suggested eight indicators (A, C, A+C, T, G, W, T_A, T_D) of genealogy reproduction ability. They considered the reproduction conditions of the academic genealogy, mainly, the cultivation of students by tutors and the inheritance promotion and development of the genealogy. As members of the dissertation committee have less influence on students, their roles are ignored in the present study. Consequently, we exclude the C and A+C indices, and adopt the remaining six indicators (A, T, G, W, T_A, T_D) as the evaluation dimensions in the reproduction ability analysis of the academic genealogy.

3.2 Academic influence forces of academic genealogy

The academic influence forces of a scientist refers to the degree to which a scientist is recognized by academia or peers. It mainly reflects the academic status of a scholar in the field and the degree to which academic peers and the general public recognize, value and cite their scientific research results. As is well known, an academic genealogy is influenced by the joint efforts of every member in the genealogy, but the academic influences and the academic contributions differ among the members. In this subsection, we quantitatively describe the total influence forces of a genealogy and identify its most influential members in each generation. For the academic influence of academic genealogy, we had a detailed discussion in our previous study (Lv & Chang, 2017).

3.2.1 Scales of individual academic influence forces

(1) Indicators of individual academic influence forces

The individual academic influence forces is an important quantitative index for investigating the outstanding individuals in a genealogy. How, then, can we measure the academic influence forces of a scientist? The long-term academic influence of individuals can be indicated by the h index, which is reasonable and easy to operate. However, when evaluating the academic influence of academic pedigree, the h index has some inherent defects. Previously, we found a significantly higher intensity in cooperation within an academic genealogy than cooperation among members in different genealogies (Chang, Lv, & Zhang, 2016). When the same article is written by several authors in the same academic genealogy, the same article contributes multiple times in the h index calculation. Moreover, as the authors' contributions to the same article are unequal, the academic influences of individuals cannot accurately

measure the real academic situation of each scholar. Therefore, the h index will lead to an unfair assessment.

The w index is a variant of the h -index, it is also called the weighted h -index. It was proposed by the academician (Zhang, 2009; Zhang, 2009a), who considered that the literature honor of one of multiple authors of an article, should be distinguished based on the contribution of each author. In addition to the w index, there are some variants of the h index, such as h_i , h_a , h_m , pf , ph and so on (Bornmann, Mutz, & Daniel, 2008; Du & Zhang, 2011), compared with these indexes, the w index is considered more comprehensive, and the the academician Zhang has established a website, which is more convenient for calculation. Therefore, the w index can reflect the author's academic contribution more accurately than the h index and the other variants. Academician Zhang proposed the author's w index that can be calculated by multiplying the number of citations of the paper by the author's weight coefficient.

Zhang proposed two principles for calculating an author's weight coefficient. First is the honor-third principle, which divides the honor of a paper into three parts. The first and corresponding authors are weighted by 1, and the weights of the remaining authors sum to 1. Second is the linear principle, which weights the first and corresponding authors by 1, and distributes the remaining honor by decreasing arithmetic progression of the remaining authors' order in the list. For example, consider a five-author paper with the last being the corresponding author. The first and corresponding authors are both weighted by 1, and the 2nd, 3rd, and 4th authors are proportional to 4, 3, and 2, respectively, so their weight coefficients are $4/9$, $3/9$, and $2/9$, respectively (note that $9 = 4 + 3 + 2$).

The w index (modified h index) solves the problem of repeated calculation of literature contributions, and also weights the actual citations by the sequence of the authors on the title page. The modified h index better indicates the true contribution of each author to the literature, improving the discrimination ability of the system among scholars and removing the "lack of sensitivity" shortcomings of the original h index (Zhang, 2009).

Due to the limited time and capability, this study considers that academic influence is contributed solely by academic papers, with no contributions by academic awards and academic part-timers. Therefore, the academic influence i of a scientist is expressed as

$$i = w \quad (1)$$

The calculated i directly reflects the outstanding individuals in the genealogy, especially as the measurement of these outstanding individuals is objective and accurate.

3.2.2 Academic influence forces of different generations

When examining the academic influence forces of an academic genealogy, one must consider the overall influence forces of the genealogy. The comprehensive influence forces of disciples in one generation not only reflects the temporal evolution of the discipline or field to a certain extent, but also provides the evolution direction of the genealogy. The academic influence forces of different generations in the genealogy is given by

$$J = \sum_1^M w_{GM} \quad (2)$$

The indicator G , used in the reproduction ability analysis of the academic genealogy, indicates the intergenerational ability of an individual in the genealogy. In the above expression, G is a recursive factor starting from the zeroth generation (the founder of the genealogy), and M is the number of people in the same generation. Thereby, w_{GM} is the academic influence of the M th member of the G th generation.

3.2.3 Total academic influence forces of academic genealogy

The total academic influence forces of the academic genealogy is contributed by each member of the genealogy. Assuming that the academic influence forces contributed by the members is equal in all historical periods and over all mentors or disciples, the total academic influence is obtained by summing the academic influences of all genealogy members as follows:

$$R = \sum_0^G \sum_1^M w_{GM} \quad (3)$$

where w_{GM} is the narrow sense academic influence forces (importance) of the M th member of the G th generation.

3.2.4 Contribution of individual members to the academic influence forces of academic genealogy I

Individual members contribute not only their own influences to the academic influence of an academic genealogy, but also those of their disciples. David and Hayden (2012) considered that different intergenerational members make different contributions to the genealogy, with further intergenerational members making smaller contributions. To accommodate this idea, they weighted the intergenerational members by $(1/2)^{n-1}$, where n is the number of members for which the intergenerational contribution halves in the current generation. In fact, intergenerational effects do contribute to the academic influence.

Following David and Hayden (2012), we thus define the contributions of individual members to the academic influence of an academic genealogy as follows:

$$I = \sum_{g=0}^G \sum_{m=1}^M \left(\frac{1}{2^g} \times w_{GM} \right) \quad (4)$$

where I , G , M , and w_{GM} are defined as above.

3.3 Two-dimensional evaluation system for the academic genealogy

Based on the academic genealogy fecundity and academic influence index derived in previous studies, we constructed a two-dimensional evaluation system for academic genealogies. The indices are described in Table 1.

Table 1. Indices in the two-dimensional evaluation system for academic genealogy.

First grade indexes	Second grade indexes	Investigation content
academic fecundity	A: Summed number of times an individual has served as an advisor on a dissertation T: Total number of descendants in an individual's family tree G: Summed number of generations of descendants of an individual W: Total number of descendants in the largest generation in an individual's family tree T_A: Total number of descendants in an individual's family tree who went on to become advisors themselves T_D: Calculates the decaying influence of descendants in an individual's family tree	Reflects the number of students trained by that mentor. Reflects the total number of disciples in the genealogy. Reflects the number of generations of academic genealogy reproduction. Reflects the most prosperous generation status of the academic genealogy. Reflects the number of members with inheritance ability in the genealogy.
academic influence forces	i: Individual academic influence forces J: Academic influence forces of different generations R: Total academic influence forces of an academic genealogy I: Contribution of individual members to the academic influence forces of an academic genealogy	Reflects the general situation of the number of members in the academic genealogy from the first generation. Reflects the outstanding academic individuals in the genealogy. Reflects the outstanding generation in the genealogy. Reflects the academic status of the genealogy. Reflects a member's contribution to the academic influence of the genealogy.

4 Results and discussion

Using the evaluation system of the scientists' academic genealogy, we can characterize the development and evolution of the academic genealogy, compare the academic influences of different genealogies, and evaluate individuals' contributions to the inheritance and evolution of the academic genealogy. Whether the evaluation system needs to be inspected and improved in practice can also be assessed. In the

following subsections, the academic pedigree evaluation system will be verified on the academic genealogy of Liu Tungsheng.

4.1 Liu Tungsheng's profile

Liu Tungsheng (1917–2008) was a well-known Chinese geologist who made remarkable contributions to vertebrate paleontology, Quaternary geology, environmental geology and environmental science. He studied the Tibetan Plateau and the polar regions, and was known as the father of loess and the creator of loessology. In 1946, he began working at the central geological survey and initially followed Mr. Yang Zhongjian in vertebrate paleontology research. This work gradually exposed him to Quaternary geology, to which he formally changed his research interests when the academic focus in China switched to this area in 1956. Liu created the first specialized research institutions of Quaternary Geology in China (the Institute of Earth Environment and the Chinese Academy of Sciences) and trained 46 graduate students including five academicians (An Zhisheng, Liu Jiaqi, Ding Zhongli, Zhu Rixiang, and Guo Zhengtang).

4.2 Liu Tungsheng's academic genealogy

As one of the founders of Chinese Quaternary and environmental geoscience, Liu Tungsheng created two Quaternary geology research institutions in China and trained a number of disciples in Quaternary research. He is the root of a quaternary academic pedigree that has prospered under the inheritance of Ding Zhongli, Guo Zhengtang, and the other researchers mentioned in 4.1. Table 2 lists the members of the Quaternary academic lineages descended from Liu Dongsheng. Data of Table 2 are from Liu Dongsheng's chronology and the Chinese Dissertation Database. The table refers to Liu Tungsheng as the first generation (abbreviated to 1G) member of the academic genealogy. The second generation (abbreviated to 2G) consists of 46 members including 10 post-doctoral researchers, 28 PhD students and 8 masters' students. The third generation (abbreviated to 3G) consists of 217 disciples of 25 second-generation mentors. Data were taken from Quaternary research websites and China's database of published theses.

4.3 Fecundity analysis of Liu Tungsheng academic genealogy

Academic fecundity directly quantifies the development of a genealogy, enabling comparison with the development and growth of the genealogy and a different genealogy.

Table 2. Structure of the Liu Tungsheng academic genealogy.

First generation	Second generation (46)	Third generation (217)
Liu Tungsheng	Guo Zhengtang (21)	PhD (15): Wu Haibin*, Dai Ying*, Wu Chunlin, Xiaou Goqiao, Ge Junyi, Yao Zhengquan, Wei Jianjing, Guo Qingzhen, Yin Qiuzhen, Zhang Zhongshi*, Liu Jinfeng, Peng Shuzhen, Qiao Yansong, Zhang Yan*, Chang Lin;
Liu Tungsheng	post-doctoral (10)	Master (6): Zhou Xin, Zhao De'ai, Liang Meiyuan, Yu Yanyan, Sun bin, Yao Xiaofeng
	Qin Xiaoguang (4)	PhD (2): Mu Yan* Zhang Lei; Master (2): Wu Jinshui, Yin Zhiqiang
	Tan Ming (4)	PhD (2): Hou Juzhi*, Duan Wuhui; Master (2): Tian Lijun, Tao Tao
	Xiao Jule (7)	PhD (3): Yan Jia, Si Bin, Li Yuecong*; Master (4): Liang Wendong, Zhou Lang*, Wu Jintao, Li Hongmei
	Li Yumei (3)	Master (3): Tao Qianye, Wang Lixian*, Sun Fengrui
	Yang Xiaoyan (2)	Post-doctoral (1): Li Quan*, Master (1): Wan Zhiwei
	Wang Qian, Zhao Hua, Cai Binggui, Paul D. White	
	Sun Jimin (10)	PhD (4): Yang Lirong*, Lv Tongyan, Liu Bin, Shi Caidong*, Lin Xu, Zhang Jiliang; Master (4): Gong Yingzeng, Huang Xiaogang, Han Peng*, Sun Gaoxuan
	Liu Jiaqi (20)	Post-doctoral (1): Cao Yu*; PhD (17): Sui Shuzhen, He Huaiyu, Dong Dong*, Li Xin*, Xu Kejian, Liu Yalei*, Sui Jianli, Liu Wenyue, Huang Shiyun*, Ni Yunnan, Ma Shuopeng, Zhang Nianfu*, Mu Yan*, Liu Qiang, Wang Wenyuan, Zhong Hua*, Cai Chuanqiang; Master (2): Zhang Guoping, Song Chunyu
	Ding Zhongli (19)	Post-doctoral (5): Wu Fuli, Yang Shengli, Tian Jun, Du Shuisheng, Zhao Hua; PhD (10): Yang Shiling*, Wang Xu*, Jiang Hanchao, Ji Junliang, Chen Zuoling, Xie Jing*, Yang Lirong*, Zhao Shujun, Hou Shengshan, Dong Xinxin; Master (4): Gao Ling, Zhou Bin, Ding Feng, Chen Zhuo
	Zhu Zhaoyu (12)	PhD (11): Ouyang Tingping*, Jiang Bo*, Liang Chunge, Xie Jiubing, Zhao Shengli, Yang Tian, Sun Bo, Fu Shuqing*, Su Ruixia, Xu Ruisong, Qiu Shifan; Master (1): Tian Chengjing
	Nie Gaozhong (3)	PhD (1): Zhang Shimin; Master (2): Deng Yan, Liang Fang
	Xiong Shangfa (3)	PhD (1): Lu Haijian, Master (2): Zhou Ru, Yang Ping
	Lv Houyuan (4)	PhD (3): Wang Shuyun, Zuo Xinxin; Dong Yajie; Master (1): Jia Jiwei
	Yu Kefu (7)	PhD (7): Yan Hongqiang*, Pan Wenliang*, Chen Tianran, Zhang Huiling, Li Shu, Zhao Meixia*, Huang Bojin; Master (5): Tian Cuicui, Zhou Jie*, Xiao Jinjun*, Lin Ziyun*, Huang Lingying
	Hou Juzhi (1)	Master (1): Zhang Wenjing*
	Liu Xiuming (5)	Master (5): Li Pingyuan, Liu Zhi, Guo Hui, Feng Hua, Ma Mingming
	Jiang Wenying (2)	Master (2): Cheng Yufen, Yang Xiaoxiao

Table 2. Continued

First generation	Second generation (46)	Third generation (217)
	Zhu Rixiang (26)	Post-doctoral (5): Lv Lianqing, Shi Yonghong, He Huaiyu, Li Yumei, Wang Fei; PhD (20): Wang Hongqiang, Ge Shulan, Liu Jian, Yao Haitao, Shu Mengting, Wang Yongcheng, Li shihu, Shen Xiaoli, Liu Chengying, Shi Ruiping, Zhang Benhua, Huang Sheng, Ge Kumpeng, Li Xin, Shi Caidong, Qin Huaifeng, Song Shujun, Tian Lili, Cai Shuhui, Liu Shangchi; Master (1): Xiao Bo
	Chen Yue, Li Feng, Cong Shaoquan, He Deming, Ren Jianzhang, Wang Zhenhai, Zhong Hua, Luo Yunli, Wang Xianfeng, Jin Guiyun, Wang Luo, Wu Wenxiang, Wang Daojing, Zhang song, Jin Chunsheng, Liu Ping An Zhisheng (41)	PhD (31): Zeng Cheng, Tan Liangcheng*, Zhang Xiaoye, Fu Chaofeng*, Xu Xinwen*, Ning Youfeng*, Liu Bin*, Wang Sheng*, Liu Suixin*, Ai Li*, Zhang Haiwei*, Dong Jibao, Lu Fengyan, Li Hongkai, Kang Shugang*, Zhan Changlin*, Wang Jin*, Dong Jungang*, Han Yongming*, Lan Jianghu*, Zhang Fan*, Li Zhenghua, Lu Huayu, Zhao Jiangtao*, Sun Qianli*, Wu Feng*, Zhu Chongshu*, Sun Donghui, Zhang Peng, Xu Tingting, Li Yun Master (10): Tan Liuqin*, Hu Weiguo*, He Liu*, Liu Xiaoyan*, Hou Zhaozhua*, Zhang Ling*, Lin Benmei, Jiang Yi*, Ren Jianzhang, Guo Panlin* Master (1): Li Bo PhD (1): Peng Xianzhi * PhD (1): Wang Guoan; Master (1): Chu Jun PhD (4): Li Dong, Wang Daojing*, Chen Hehai, Sun Huiguo Master (2): Wu Lei, Dai Guoliang PhD (2): Yang Shiling, Liu Zongxiu; Master (3): Wang Pan, Hu Bin, Zhou Qian Post-doctoral (3): Liu Lianwen, Zhou Bin, Zhang Xinrong; PhD (2): Huang Xiangrong, Yang Wenguang; Master (6): Ji Junliang, Qing Ziqi, Liu Rui, Chen Guocheng, Wang Ke, Mei Xi*
	Zhao Xitao (1) Jia Rongfen (1) Han Jiamao (2) Han Jingtai (6) Gu Zhaoayan (5) Zheng Hongbo (11) Xu Li	

Note: “*” indicates that the student was jointly cultivated by two or more mentors. The number in the parenthesis is the number of disciples. The number of third-generation disciples is constantly increasing. Therefore, our data is until 2015.

Table 3. Fecundity analysis parameters of the Liu Tungsheng academic genealogy.

Indicators	Liu Tungsheng	Implication
A	46	Liu Tungsheng trained 46 graduate students.
T	263	This genealogy has a current total of 263 disciples.
G	2	This genealogy has two generations of disciples.
W	217	The largest number of disciples is 217 in the third generation.
T _A	26	There are 26 mentors in the genealogy.
T _D	154.5	Liu Tungsheng's contribution to the genealogy reproduction is 154.5.

There are 264 members in Liu Tungsheng's academic genealogy: one first-generation member, 46 second-generation members, and 217 third-generation members. Among the 25 mentors (at least) in the second generation, An Zhisheng, Zhu Rixiang, Liu Jiaqi, Guo Zhengtang, and Ding Zhongli have mentored 38, 25, 20, 20, and 19 disciples, respectively. These second-generation members formed their own genealogy branches. Including his disciples' contribution to the academic genealogy, Liu Tungsheng's contribution to the academic genealogy was 154.5.

4.4 Academic influence forces of Liu Tungsheng's academic genealogy

When measuring the academic influence forces index of an academic genealogy, we must investigate the individual academic influence of every member in the genealogy, namely, the improved h index (w index) of every member. To measure this indicator, we obtained the data of high-level papers published by the genealogy members from the Science Citation Index (SCI). The Web of Science™ Core Collection retrieves the surname (in full) and first name (abbreviated) of each member. The data are screened and cleaned based on the research areas or affiliations of the authors, then downloaded as full records.

For calculating the w indices of the genealogy members, we computed the weight coefficients on the free website established by Zhang (<http://www.wcitation.org/>). The w index requires five information parameters for each paper: No. (the serial number of the article), n (the total number of authors), k (the w index calculated by ranking the scholars in the article), cit (total number of citations), and cor (the position of the corresponding author in the list of names). The member data of the inner Liu Tungsheng academic genealogy were downloaded separately and the imported computing site automatically calculated the total and weighted citations of the different members, and hence the h and w indices of the members. For example, Liu Tungsheng's total citations and h index are 3,704 and 36 respectively, and his weighted total citations and w index are 1,181.45 and 20.05, respectively. The calculated academic influences forces of the separate generations and all generations are presented in Table 4.

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Table 4. Academic influences forces of different generations of the Liu Tungsheng academic genealogy.

First-generation influence (J1)	Second-generation influence (J2)	Third-generation influence (J3)	General influence of academic genealogy
20.05 (1)	348.22 (46)	361.79 (217)	730.06

From the numerical values in Table 4, we find that the third-generation influence has surpassed the second-generation influence. However, as the third-generation members are generally younger, their individual academic influences forces are not fully developed. Therefore, the average influence forces of individual members is only 1.67, far below that of second-generation members (7.57). In fact, the academic influence forces of different generations in the same genealogy cannot be simply compared, because the research hotspots of a certain field or research direction in different periods are greatly affected by the development of disciplines and national policies. Changes in research hotspots affect the citations of papers, thereby indirectly affecting intergenerational academic influence forces. But from the influence forces of different generations in Liu Dongsheng’s pedigree, we can see from a macro perspective the process of this pedigree from inception to development to prosperity. In addition, when studying two different pedigrees of the same discipline at the same period, the intergenerational academic influence index J allows us to see the differences between the two pedigrees in different periods in more detail.

Because there are too disciples in the third-generation, and their individual academic influence forces are still relatively low, so we only display the academic influences forces of the first- and second-generation individuals and their contributions to the academic genealogy influence forces in Table 5. Second-generation members with outstanding academic influence forces are Guo Zhengtang, Sun Jimin, Ding Zhongli, Lv Houyuan, Zhu Rixiang, and An Zhisheng, their academic influence forces are 22.09, 21.59, 20.85, 21.87, 21.22, and 21.26 respectively. The collective academic influence forces of these six members exceed that of Liu Tungsheng. In a sense, higher academic influence means higher academic title, among them, An Zhisheng, Guo Zhengtang, Ding Zhongli, and Zhu Rixiang are academicians of the Chinese Academy of Sciences, and Lv Houyuan and Sun Jimin are candidates for academicians.

A scholar’s contribution to the academic genealogy includes the academic influence forces of both the scholar and his or her disciples. As shown in Table 5, Liu Tungsheng’s individual academic influence is 20.05, but his total contribution to the academic genealogy influence is 296.5. Similarly, the total influence contributions of Liu Jiaqi, Ding Zhongli, Zhu Rixiang, and An Zhisheng exceed their individual influences. Although the academic influences of Sun Jimin and Lv

Houyuan are similar to those of Ding Zhongli and Guo Zhengtang, these researchers took few students, so the contributions of their disciples are not very significant.

Table 5. Academic influence forces of members in Liu Tungsheng academic genealogy and their contribution to academic genealogy.

1G member	Contribution to academic genealogy		2G Member	Individual academic influence	Contribution to academic genealogy
Liu Tungsheng	$20.05 + (120.35 + 303.22 + 129.33) / 2 = 20.05 + 552.9 / 2 = 296.5$	Post-doctor	Guo Zhengtang	22.09	51.39
			Qin Xiaoguang	6	9.69
			Tan Ming	6.49	11.98
			Xiao Jule	14.25	23.03
			Li Yumei	1.58	2.08
			Yang Xiaoyan	5.32	7.73
			Wang Qian	4.86	4.86
			Zhao Hua	5.25	5.25
			Cai Binggui	4.37	4.37
			Paul D. White	0	0
		Ph.D.	Sun Jimin	21.59	29.98
			Liu Jiaqi	7	18.07
			Ding Zhongli	20.85	47.57
			Zhu Zhaoyu	4.21	14.18
			Nie Gaozhong	1.43	4.645
			Xiong Shangfa	8.47	9.78
			Lv Houyuan	21.87	24.67
			Yu Kefu	12.33	16.56
			Hou Juzhi	7.18	8.66
			Liu Xiuming	16.35	17.97
			Jiang Wenying	6.96	8.83
			Zhu Rixiang	21.22	33.04
			Chen Yue	2.8	2.8
			Li Feng	8.66	8.66
			Cong Shaoguang	2.86	2.86
			He Deming	0	0
			Ren Jianzhang	6.36	6.36
			Wang Zhenhai	1	1
			Zhong Hua	3.4	3.4
			Luo Yunli	4.82	4.82
			Wang Xianfeng	10.29	10.29
			Jin Guiyun	2.33	2.33
			Wang Luo	1.55	1.55
			Wu Wenxiang	5.51	5.51
			Wang Daojing	4.26	4.26
			Zhang song	1.7	1.7
			Jin Chunsheng	5.24	5.24
			Liu Ping	8.5	8.5
		Master	An Zhisheng	21.26	62.42
			Zhao Xitao	2.67	2.67
			Jia Rongfen	2.96	8.08
			Han Jiamao	8.02	8.02
			Han Jingtai	6.68	14.93
			Gu Zhaoyan	6.97	12.88
			Zheng Hongbo	10.71	20.34
			Xu Li	4.78	0

Research Paper

Six members of the second generation of the academic genealogy (Guo Zhengtang, Sun Jimin, Ding Zhongli, Lv Houyuan, Zhu Rixiang, An Zhisheng) exerted higher individual academic influence than their mentor, Liu Tungsheng. This indicates that both the quantity and quality of their published papers are very high. However, Liu Tungsheng is more famous worldwide than his disciples. Therefore, the academic influence forces of different generations cannot be compared solely by the w value, as they also depend on the development speed of the subject in the generational period, social factors, and other influencers. The academic career of Liu Tungsheng was blighted by the 10-year Cultural Revolution, and his papers did not appear in international journals until 1981 (when Liu was 64 years old). In the 1990s, China's geology entered a period of rapid development, so the impact of his students influenced by the Cultural Revolution is relatively small. Consequently, the academic influence forces of scientists in different generations and specializing in different subjects are not directly comparable.

Liu Tungsheng's contribution to the academic genealogy is made up of his individual academic influence, half the academic influence of second-generation members, and one quarter of the academic influence of third-generation members. From Table 5, we find that Liu Tungsheng's individual academic influence is 20.05, whereas the academic contributions of his second-generation members sum to 552.9. Ultimately, Liu Tungsheng's contribution to academic genealogy reaches 296.5. Although the individual influence forces of the six prominent second-generation members are almost the same, their individual contributions to the academic genealogy differ widely. For instance, the individual academic influences of Guo Zhengtang and An Zhisheng are 22.09 and 21.26 respectively, and their total contributions to the academic genealogy influence are 51.39 and 62.42 respectively. Meanwhile, the individual academic influences of Sun Jimin, Ding Zhongli, Lv Houyuan, and Zhu Rixiang are almost 21, but their summed contributions to the academic genealogy are 29.97, 47.57, 24.66, and 33.04, respectively. Therefore, although the individual academic influences of these six members are very similar, their summed weighted influence forces are highest for An Zhisheng, followed by Guo Zhengtang, Zhu Rixiang, Sun Jimin, and Lv Houyuan. From the above discussion, we can see, the contribution of individual members to the academic influence forces of academic genealogy can better demonstrate a summed academic influence forces of a genealogy or branch, and also can demonstrate the ability of academic inheritance of individual members or a genealogy.

5 Conclusions

We introduced indicators of academic genealogy influence forces to improve the existing quantitative evaluation system of academic genealogy, and to enrich the evaluation methods of academic research. Based on the research results of Russell, this study chose six indicators (A , T , G , W , T_A , T_D) as the evaluation dimensions in an academic genealogy fecundity analysis. Considering the limited research population, discipline, and data sources, this study also uses the w index (improved h index) as the main indicator of individual academic influence forces. In future work, we will integrate scholars' academic awards and academic part-timers into the w index for a comprehensive reflection of scholars' individual academic influences. Furthermore, we proposed four indices that reflect the academic characteristics of a genealogy; the i index (individual academic influence) that reflects a member's academic status in the genealogy, the J index (total academic influence of a generation) that reflects the academic statuses of different generations, the R index (total academic influence forces of the academic genealogy) that reflects the total academic status of the genealogy, and the I index (academic influence forces of the academic genealogy considering the intergenerational contributions) that reflects all members' contributions to the academic influence forces of the genealogy. All of these indices are measures of the genealogy academic influence forces. By the verification using the genealogy of scientist's Liu Dongsheng, we found the Two-dimensional evaluation system for the academic genealogy can better demonstrate the reproduction and the academic inheritance ability of a genealogy.

Finally, we selected the w index (improved h index) as the main indicator of individual academic influence. This index overcomes the situation of repeated measurements and distortion of results in the academic genealogy. The h index remains applicable under appropriate conditions.

Theoretically, the constructed evaluation system of scientists' academic genealogy can characterize the development and evolution of the genealogy, and can compare the academic statuses and personnel developments of different academic genealogies in the same discipline and the same generational age. Improvements to the present system will be ongoing.

Acknowledgements

We would like to express our thanks to the Humanities and social science fund of the Ministry of Education (Grant Number: 15YJA870009) for their financial support for this work.

We would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the quality of the paper.

Author contributions

Ruihua Lv (lvrh@bit.edu.cn) proposed the original idea and improved the manuscript; Huan Chang (Muis@ui.ac.id) Calculated the relevant data in the paper and wrote the first draft.

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