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Analysis of Key Elements of Technological Innovation Talents Based on Complex Network Theory

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Abstract. In order to conduct a systematic study on the key factors in the process of technological innovation talents (TIT) training in China and to develop training strategies for high level TIT, the paper summarizes the related factors of TIT into 32 statistical indexes of Seven Quotients (SQ) and builds an evaluation index set of key factors of TIT, based on the relevant research achievements of TIT. Then with the application of the complex network theory, a TIT complex network topological model is constructed with the sample data of outstanding and ordinary TIT. Indexes from the perspectives of local, global and comprehensive attributes are built to evaluate the significance of complex network nodes and analyze the key factors of TIT of different levels. In the end, TIT complex network survivability is tested under random attack and deliberate attack with "network weighted average shortest path" and "network natural connectivity" indexes, providing training theories and decision-making references for TIT personalized training and compensatory training mechanism under the condition of insufficient key factors.

1. Introduction

Nowadays, science and technology plays an important role in all fields of human life. Similarly, technology has an increasingly decisive influence on the development of social productivity. However, the most important thing in the development of science and technology is innovation. The source of innovation is the embodiment of the all-round ability of Technological Innovation Talents (TIT).

At present, most of the China's research on the strategy of TIT is only a partial description of the scope of reductionism. Some of them are qualitative research on the flow of technological innovation talents and the quality training of professional science and technology talents. The other part is a solution focusing on the creation of science parks and the specific problems of regional TIT. But any event is an organic systemic problem. Therefore, the related issues of TIT should be regarded as a complex and huge system. It is necessary to systematically study the key elements of TIT and summarize the common elements of science and technology innovation talents in order to form a complete key system of TIT [1].

This paper combines reductionism and holism，To build a key element system of “seven quotients(SQ)” for TIT, thus enriching and expanding the theoretical system of education in China. At the same time, using the relevant theories and methods of complex networks, the key elements of TIT are deeply explored and quantified. Combining qualitative and quantitative research on the role of different factors in the growth of TIT, analyzing the key elements of different levels of scientific and technological innovation talents and the network anti-destructive performance against different

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attack strategies. Provide theoretical and empirical support for the targeted cultivation of TIT and the cultivation of factor compensation for special populations.

2. TIT Key Factors Index Set

In order to improve the individual's TIT from ordinary to excellent quality and achieve the goal of training more outstanding TIT, this paper divides the quality characteristics of ITI into four levels: knowledge accomplishment, personality quality, healthy physique and sound psychology. The SQ are used to measure the key elements of TIT. Different indexes and impact factors under each quotient are used to measure the quotients to build a specific and detailed TIT key factors system.

Based on a literature review, the paper defines SQ as follows:

① Health Quotient (abbreviated as HQ) measures an one’s physical condition, including healthy awareness(HQ1), self-care ability(HQ2), physical fitness(HQ3) and sports coordination ability(HQ4).

② Intelligence Quotient (abbreviated as IQ) is the ability to understand objective things and to use knowledge to solve practical problems[2]. Based on a literature review of relevant IQ research and viewpoints of genetic medicine, the paper identifies 8 key factors of IQ, namely parental genetic basis(IQ1), education level(IQ2), attention and observation level(IQ3), logical thinking ability(IQ4), memorizing ability(IQ5), adaptability(IQ6), imagination(IQ7) as well as language comprehension and expression ability(IQ8)[3].

③ Knowledge Quotient(abbreviated as KQ) refers to one’s ability to summarize and reflect the physical form and movement rules of the objective world through logical thinking, and to transform the information of the objective world into knowledge[4].Based on individual cognitive processes such as acquisition, processing and storage of information and combined with pedagogics-related concepts, KQ is categorized into individual knowledge acquisition ability(KQ1), knowledge storage(KQ2) and knowledge application ability(KQ3) in this paper[5].

④ Emotional Quotient(abbreviated as EQ) is one's ability to control and express oneself and others' emotions by perception. Emotional Quotient mainly reflects individual emotional cognitive ability(EQ1), emotional expression ability(EQ2), emotional application ability(EQ3) and emotional control and adjustment ability(EQ4)[6].

⑤ Moral Quotient[7] (abbreviated as MQ) is a data index to measure the level of individual moral quality. Through influential factors screening, the paper proposes to use most influential indexes such as social responsibility(MQ1), devotion(MQ2), dedication(MQ3), honesty(MQ4) and so on to measure individual MQ.

⑥ Will Quotient (abbreviated as WQ) refers to one's will quality level and the psychological process of overcoming the external and internal difficulties to achieve the goal under certain motivations[8]. In light of TIT features, the paper draws to the conclusion that WQ is supposed to include individual independence(WQ1), proactivity(WQ2), controlling ability(WQ3), confidence(WQ4), executive force(WQ5), and pressure tolerance ability(WQ6).

⑦ Position Quotient (abbreviated as PQ) is the quotient measuring one's positioning ability, which refers to the one's rapid and accurate judgment of his or her position in the society and the appropriate formulation of goals or the decision-making ability to grasp the success[9]. It is proposed in this paper that PQ is measured through individual positioning ability(PQ1), decision-making ability(PQ2) and organizational and collaborative ability(PQ3).

3. TIT Complex Network Modeling

If the individual SQ system is regarded as a network composed of SQ index, SQ index and 32 statistical indicators within each quotient are regarded as nodes in the network, if there is a strong correlation between the two indicators, the network nodes represented by the two indicators are connected[10]. Then, the SQ system can be transformed into a complex network system consisting of 32 index nodes, and The complex network system of SQ index association is shown in Fig 1.

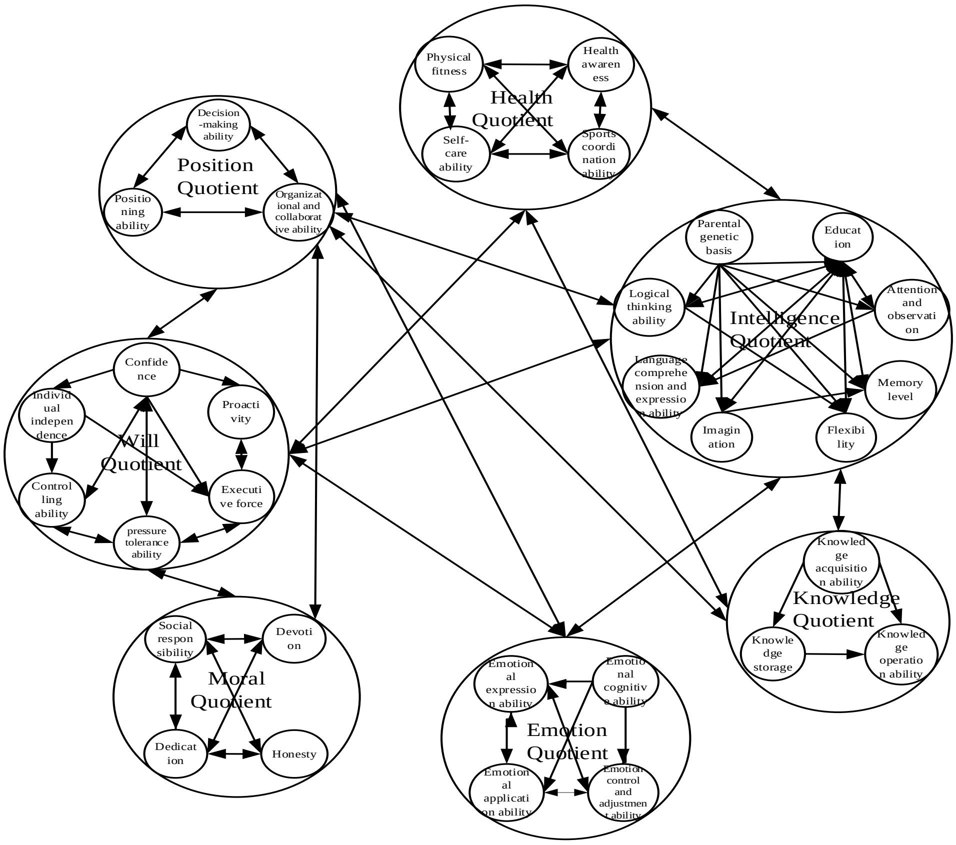

Figure 1 Topological structure of the SQ network of TIT and their subnet

Table 1 Values of characteristic parameters of the SQ network and each subnet of TIT

Parameter name	SQ Network	HQ Subnet	IQ Subnet	KQ Subnet	EQ Subnet	MQ Subnet	WQ Subnet	PQ Subnet
(1)Average Node Degree of Network	3.71	3.00	4.00	2.00	3.00	2.50	3.33	2.00
(2-1)Average path length	1.38	1.00	1.43	1.00	1.00	1.17	1.33	1.00
(2-2)Network diameter	2.00	1.00	2.00	1.00	1.00	2.00	2.00	1.00
(3)Clustering coefficient	0.71	1.00	0.86	1.00	1.00	0.83	0.67	1.00

Further analysis of Table 1 shows that the main characteristics of the SQ network of TIT are as follows:

(1) The average network degree of the SQ network of TIT is 3.71, which indicates that there is a direct causal relationship between each quotient and four other quotients in the whole network. That is, the change of each quotient may cause the change of four quotients directly related to the dynamic evolution of the growth of TIT. As far as the quotient subnet is concerned, the average degree of the network of the IQ subnet and the IQ subnet is slightly larger than that of the other five subnets, which indicates that there are more direct interaction networks between the two subnets.

(2) The average path length of the SQ network is 1.38, which indicates that the change of one quotient affects the change of other quotients through an average of 1.38 network edges. The average path length of each quotient subnet is smaller than that of the whole network except for the IQ subnet, which reflects that the direct role of each quotient subnet is more closely related. The diameter of the whole network of SQ of TIT and their sub-networks are less than or equal to 2, which indicates that the change of other quotients and other statistical indicators can be indirectly affected by two steps at most, whether between the seven quotient indicators or among the

statistical indicators within each quotient.

(3) The clustering coefficients of the seven quotients network of scientific and technological innovators are 0.71, and the clustering coefficients of the seven sub-networks are between 0.67-1. It shows that the clustering effect is obvious among the seven quotient networks and within the sub-networks. The clustering coefficients of the statistical indicators of health quotient, knowledge quotient, emotional quotient and location quotient are all 1. That is to say, any two nodes in the network are directly connected, and the internal statistical indicators of IQ subnet and MQ subnet and WQ subnet are also closely related and highly coupled.

4. Importance Evaluation of Complex Network Nodes for TIT

Aiming at the problem of insufficient evaluation index in the evaluation of node importance due to the use of node contribution and node efficiency [14], this paper further combines the mutual information evaluation index in undirected weighted network [13], Starting from the local, global and comprehensive properties of nodes, a set of improved node importance evaluation models for comprehensive measurement indicators is constructed.

The index NID is a comprehensive measure index of complex network structure relationship, considering the influence of node contribution, mutual information, node efficiency and feature vector index on the importance of nodes in complex networks. Through comprehensive evaluation of the attributes of nodes, a comprehensive evaluation of the importance of nodes in a complex network is realized. The calculation formula for the comprehensive measure index NID is defined as Eq.1:

$$NID(i)=\lambda(e_i \times \sum_{j=1.\, j\neq i}^{n} \eta_{ij} e_j (\alpha \frac{k_{jin}}{\langle k_{in} \rangle^2} + \beta \frac{k_{jout}}{\langle k_{out} \rangle^2})) + \mu(C_E(i) \times \sum_{j=1,\, j\neq i}^{n} I(i,j)) \tag{1}$$

η_{ij} represents the adjacency matrix elements of the complex network, λ and μ respectively reflect the influence factors of the two sets of comprehensive measure indicators.

In order to study the cultivation of high-level technological innovation talents, this paper mainly studies outstanding and general technological innovation talents, and uses the complex network node importance evaluation model constructed in this section to systematically evaluate the importance of two types of talent network nodes, and mining key elements in the process of cultivating outstanding technological innovation talents. The ranking results of the nodes (indicators) of the outstanding technological innovation talent samples determined by each method are shown in Table 2:

Table 2 Comparison of the importance ranking results of the sample indicators of outstanding TIT determined by each method

Statistical indicators		Algorithm of [11]		Algorithm of [12]		Improved algorithm in this paper					
						λ=0.4; μ=0.6		λ=0.5; μ=0.5		λ=0.6; μ=0.4	
		Measure	Ranking	Measure	Ranking	Measure	Ranking	Measure	Ranking	Measure	Ranking
HQ	(HQ1)	0.054	26	-0.058	25	-0.013	27	0.002	26	0.009	28
	(HQ2)	0.061	20	0.062	6	0.062	12	0.061	15	0.062	16
	(HQ3)	0.062	19	-0.026	21	0.009	23	0.018	22	0.026	23
	(HQ4)	0.058	22	-0.093	29	0.036	17	0.068	13	0.100	11
IQ	(IQ5)	0.050	28	-0.150	32	-0.064	32	-0.034	31	-0.020	32
	(IQ6)	0.097	13	0.027	9	0.055	14	0.062	14	0.069	15
	(IQ7)	0.066	17	-0.060	26	0.037	16	0.060	16	0.084	13
	(IQ8)	0.235	3	0.393	2	0.264	2	0.232	2	0.199	2
	(IQ9)	0.052	27	-0.053	24	-0.011	26	-0.002	28	0.010	27
	(IQ10)	0.071	15	-0.071	27	-0.014	28	0.001	27	0.014	26
	(IQ11)	0.110	11	0.023	10	0.061	13	0.071	12	0.080	14
	(IQ12)	0.184	7	0.005	14	0.124	5	0.153	4	0.183	3

Statistical indicators		Algorithm of [11]		Algorithm of [12]		Improved algorithm in this paper					
						λ=0.4; μ=0.6		λ=0.5; μ=0.5		λ=0.6; μ=0.4	
		Measure	Ranking	Measure	Ranking	Measure	Ranking	Measure	Ranking	Measure	Ranking
KQ	(KQ13)	0.231	5	0.006	13	0.088	10	0.113	9	0.139	8
	(KQ14)	0.038	32	-0.041	23	-0.003	25	0.007	25	0.017	25
	(KQ15)	0.045	29	-0.126	31	-0.041	30	-0.042	32	-0.016	31
EQ	(EQ16)	0.070	16	-0.025	20	0.031	18	0.042	18	0.056	17
	(EQ17)	0.118	10	-0.001	16	0.093	9	0.116	8	0.140	7
	(EQ18)	0.055	25	0.048	7	0.044	15	0.043	17	0.042	19
	(EQ19)	0.057	23	-0.105	30	-0.053	31	-0.024	30	-0.008	30
MQ	(MQ20)	0.056	24	-0.021	19	0.010	22	0.017	23	0.025	24
	(MQ21)	0.233	4	0.001	15	0.094	8	0.117	7	0.141	6
	(MQ22)	0.059	21	-0.082	28	-0.026	29	-0.012	29	0.002	29
	(MQ23)	0.041	30	-0.027	22	0.001	24	0.008	24	0.036	20
WQ	(WQ24)	0.090	14	-0.013	17	0.028	20	0.039	19	0.049	18
	(WQ25)	0.241	2	0.490	1	0.314	1	0.270	1	0.226	1
	(WQ26)	0.302	1	0.148	5	0.163	3	0.166	3	0.170	4
	(WQ27)	0.167	9	0.029	8	0.084	11	0.098	11	0.112	10
	(WQ28)	0.229	6	0.012	12	0.104	7	0.120	6	0.142	5
	(WQ29)	0.064	18	-0.013	17	0.022	21	0.026	21	0.029	22
PQ	(PQ30)	0.039	31	0.021	11	0.029	19	0.031	20	0.033	21
	(PQ31)	0.098	12	0.149	4	0.115	6	0.106	10	0.098	12
	(PQ32)	0.179	8	0.178	3	0.146	4	0.138	5	0.130	9

Further analysis of Table 2 shows that the sample of outstanding technological innovation talents is used as an example to use the literature [11], the literature [12] and the improved algorithm of this paper to rank the sample indicators. The experimental results show that the improved node importance evaluation model not only overcomes the shortcomings of the node importance evaluation information when the adjacency matrix element is 0, but also compensates for the shortcomings of directly determining the importance of the node by mutual information. The improved comprehensive measurement indicators can more objectively and comprehensively reflect the importance ranking of the key elements of outstanding technological innovation talents.

5. TIT Complex Network Survivability Simulation

As for TIT complex network survivability, individual SQ insufficiency will affect the whole SQ system, and technological innovation level. What changes of TIT complex network will SQ index insufficiency lead to and what countermeasures should be taken to promote TIT growth are also the focuses of this paper[13].

① Survivability analysis of outstanding TIT complex network

The changes of network "weighted average shortest path" and "natural connectivity " of outstanding TIT under the strategies of random attack and deliberate attack are shown in Fig 2 and Fig 3:

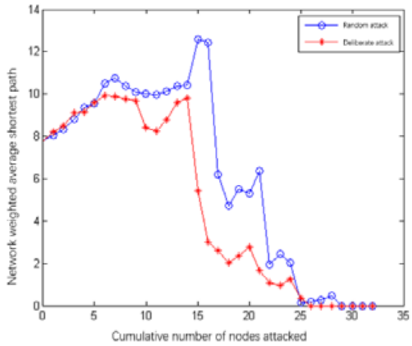

Figure 2 Changes of network weighted average shortest path

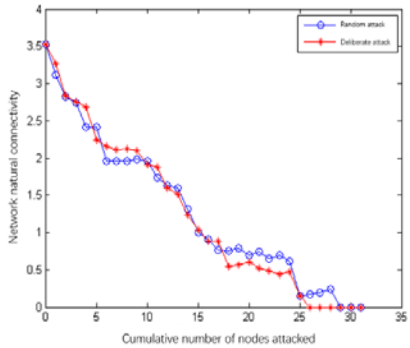

Figure 3 Changes of network natural connectivity

Fig 2 and Fig 3 indicate a very good complex network survivability of outstanding TIT samples in that the survivability indexes under the two attack strategies experience a relatively flat change before the cumulative attack nodes reach half of the total. The SQ indexes of outstanding TIT are all in a high level, and all the related indexes have been fully developed. There is no big difference between the impacts under the two different attacking strategies.

②Survivability analysis of ordinary TIT complex network

The changes of network "weighted average shortest path" and "natural connectivity " of ordinary TIT under the strategies of random attack and deliberate attack are shown in Fig 4 and Fig 5:

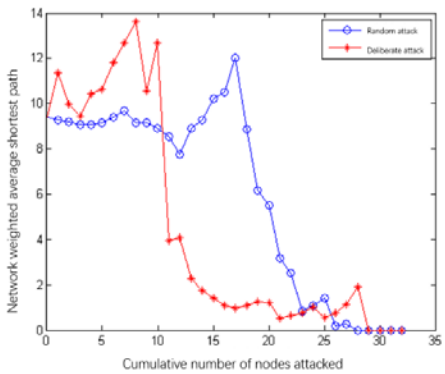

Figure 4 Changes of network weighted average shortest path

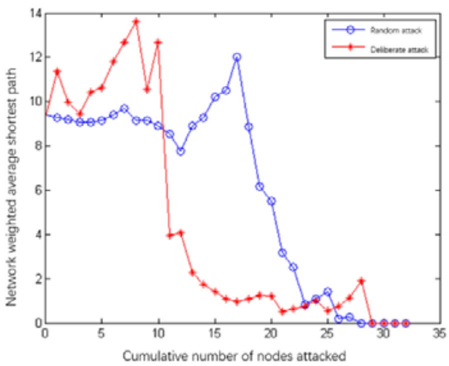

Figure 5 Changes of network natural connectivity

Figure 4 and figure 5 show a sharp increase of average shortest path value of ordinary TIT complex network under deliberate attack before attacking nodes reach 10 and a sharp decrease into 0 afterwards, while the value under random attack experience a flat change in earlier stage and a sharper decrease than deliberate attack in the later stage. In other words, deliberate attack has more impact on the network than random attack in the earlier stage while random attack has more impact in later stage. Above facts suggest that relevant capability training should be strengthened due to a weaker survivability of ordinary TIT to the important nodes.

6. Conclusions

Conclusions are drawn that ordinary TIT, in spite of possessing certain innovation abilities, have insufficient IQ, KQ and PQ due to inadequate knowledge storage ,weak logical thinking ability ,weak positioning ability and poor organizational and collaborative ability. Logical thinking ability, flexibility and knowledge accumulation should be strengthened and technological innovation ability should be improved with flexible application and expression to grow into outstanding TIT. Changes of complex network survivability show that outstanding TIT have better survivability to deliberate attack and random attack while ordinary TIT have a weak survivability to deliberate attack due to several lower index values. Therefore, it is of great significance to provide personalized training strategy to TIT of different levels.

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