INVESTIGATION OF THE LEGISLATION OF CONTROL EFFECTIVENESS OF LABOR OF SCIENTIFIC GROUPS

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Abstract: *Based on ideas of systems analysis, this paper considers problems that reduce the effectiveness of work in the scientific sphere, including inefficient group work and critical thinking, have been identified. It is intended to resolve the identified problems, and to suggest ways of increasing the effectiveness of scientific work.*

System analysis was used due to awareness of the need to choose the most effective alternative for a complex, weakly structured system of scientific work.

The authors identified 22 key concepts that affect the effectiveness scientific work and related it to both to individual productivity, and to results of group work and critical thinking. The ranking of concepts on the impact on labor efficiency has been carried out and their interrelations have been determined.

The rationale for the humanistic model of the effectiveness of scientific activity is discussed in the light of the needs of modern management and labor economics, which affect the effectiveness of the national economy.

The novelty of this work consists of holistic examination of scientific activity in relation to group work and critical thinking.

Keywords: *system analysis, group work, knowledge, cognitive modeling, critical thinking, traps of consciousness, the effectiveness of scientific work, GDP, education, labor*

INTRODUCTION

Research activity is a complex system of cognitive, economic, social, industrial, and other factors that transform and develop in accordance with ongoing social processes.

G. Leibniz, a great mathematician who was one of the initiators of the establishment of the Academy of Sciences in Russia, defined the objective of science as follows: “To achieve the humanity's welfare, that is, multiply all that is useful to people, not for the sake of indulging in idleness, but for maintaining virtue and expanding knowledge” (Science’s Role in Society, 2018).

In the 17th century, science ceased to perform the cognitive function only and became the basis of people's material, practical activities. Its role grew significantly after the scientific and technological revolution had taken place around 1935. In the 20th century the significance of science also increased due to a rapid growth of the human capital share in the national wealth of countries and rose from 30% to 80% in the largest developed and developing countries (Yu.A. Korchagin, 2005, p. 27).

The role of science will become even more indispensable in the future. While in the late 20th century the growth of human capital and, accordingly, labor productivity was in many respects due to the increasing share of highly-skilled specialists who obtained higher education, this resource has already been used up. In these conditions, science will become the most important resource for the growth of national wealth. But investment in science is a heavy burden for the country's economy. Therefore, it is important to seek ways to raise the efficiency of scientific work with account of a variety of factors. This concept has become the subject of this paper.

Research (Barro, R., J., Lee, J., W., 2001) showed that GDP per capita in different countries depends exponentially on the average number of years of education of the population. According to Orekhov V. (2016., pp. 625-635), the average contribution of a professional to the country's GDP depends exponentially on the number of years of his education according to the following formula (1):

$$\mathbf{G_L = K_L \cdot 10^{L/5}}, \qquad (1)$$

Here, L is the number of years of education of the professional, and factor $K_L \approx 125$ in international dollars of 2011 for the largest economies. This formula allows for assessing the contribution to the country's GDP of not only professionals with various education levels, but also of scientists, if their educational level is considered to be about six years longer than higher education. Such a strong influence of education on the contribution of professionals to the country's GDP makes it the main systemic driver of national welfare growth.

Formula (1) allows for deriving several important conclusions. First, the most profitable way is to increase the educational level of professionals with the highest level of skills, in particular, scientists, since it gives a greater contribution to GDP.

Secondly, it is possible to apply the formula to a group of specialists in order to determine the synergistic effect from their joint work. Such estimates show that, in principle, it is possible to achieve a multiple increase in the contribution of specialists to the country's GDP (Prichina O.S., Orekhov V.D., Shchennikova E.S., 2017, pp. 77–81). In particular, the current data on the performance of group work shows that ignificant increase in labor productivity can be achieved by forming a so-called “team” (Woodcock, M., 1979) .

However, Belbin (2004, p. 22) has shown that there are serious obstacles in organizing teamwork of highly qualified professionals, in particular, scientists. Therefore, organizing the work of scientific teams efficiently requires a systematic study.

Another way to raise the research performance involves critical thinking methods, struggle with “traps of consciousness,” and other approaches to increasing the mental work productivity, which altogether represent a standalone scientific direction (Temple Ch., 2005).

In order to analyze all issues related to the scientific performance in a holistic manner, we used the cognitive modeling method in this study (Kulinich A.A., 2010, pp. 2–15).

The purpose of this research is to identify the most significant factors and formulate proposals for scientific performance improvement programs.

1. METHODOLOGY

The system of labor activity was studied using the main function of system analysis: providing research and real labor activity with a methodology of particular functions of system analysis.

The particular functions of system analysis include:

– identification of the completeness and correctness of the diagnostic assessment of defining the main groups of elements (concepts) as a certain system of the existing state of the problematic area;

– building the aggregate structure of the strength of connections (interconnections) between the concepts of the scientific activity system;

– the phenomenon of the integrity of the cognitive matrix construction and its implementation in the decision support system (DSS);

– an analysis of the function’s value (performance);

– modeling the behavior of the interacting elements of the system on an ambivalent basis within the objective function.

The set of factors interacting within the investigated problem was ranked by means of a survey of experts by both factor magnitudes and their mutual influence. The results are provided in the form of an array of interacting ranked concepts, called a Fuzzy Cognitive Map (Kosko B., 1986, P. 65). In the future, the computer decision support system will be used to analyze the level of confidence in various factors of the system, define cumulative effects of concepts through a system of connections, and perform dynamic modeling of its behavior under the influence of control impulses.

2. RESEARCH RESULTS

2.1. Formation of the initial system of concepts

At the early stage of the study, the initial list of concepts (**e_i**) influencing scientific performance (see Table 1) was developed and their relative significance level (mathematical expectation) -**M_i** was determined, which was evaluated by 14 qualified subject experts. We used a truncated five-point scale with the following scores: 2 – low, 3 – medium, 4 – high, 5 – very high level (was not applied). Table 1 also shows the values of standard deviation **S_i** for each concept.

Table 1. Initial list of concepts affecting scientific performance

i	Concept, group (e_i)	M_i	$S_i(E_i)$
	Individual performance concepts	**3.3**	
1.	Education of the professional	3.6	0.50
2.	Intelligence quotient (IQ)	3.6	0.65
3.	Experience of the professional	3.8	0.43
4.	Communication skills, connections	3.5	0.65
5.	Foreign language skills	2.6	0.74
6.	Status of the professional	2.5	0.65
7.	Computer support systems	3.4	0.63
	Critical thinking and traps of consciousness	**3.2**	
8.	Presence of wrong judgments in the mind	3.1	0.77
9.	Influence of traps of consciousness on thinking	3.2	0.70
10.	CM enhances the knowledge analysis performance	3.6	0.50
11.	CM algorithms' performance	2.9	0.86
12.	Higher innovative skills due to CM	3.2	0.70
13.	Ability to identify issues	3.6	0.51
14.	Ability to think reflexively	3.2	0.58
15.	Ability to resist traps of consciousness	2.9	0.73
16.	Joint detection of inaccurate judgments	3.2	0.80
	Positive concepts of teamwork	**3.1**	
17.	Agreed common goal of activity	3.6	0.76
18.	Consistency of personal interests	3.1	0.73
19.	Stimuli for cooperation	3.0	0.68
20.	Presence of role performers according to R.M. Belbin	2.7	0.47
21.	An environment of mutual assistance and respect	3.6	0.63
22.	Group integrity	3.0	0.78
23.	Competence variety	3.4	0.51
24.	No-dominant work organization	2.7	0.61
25.	Teaching efficient teamwork	3.0	0.55
	Negative and neutral concepts	**2.7**	
26.	Group members seeking to dominate the group	3.1	0.66
27.	Mistrust to statements of other group members	2.9	0.73
28.	Distinction of personal goals and benefits of the members	2.9	0.77
29.	Intellectual property	2.4	0.65
30.	Leadership culture education by the society	2.4	0.50
31.	National differences in the behavior culture	2.4	0.74
	Average	**3.1**	**0.66**

Table 1 shows that the average score is 3.1. A few concepts have low significance (no more than 2.5). Therefore, it was decided to withdraw concepts 6, 29–31 from the list of main concepts. As a result, the block of negative teamwork factors became small in terms of the number of concepts, and it was decided to combine it into a common block of teamwork concepts. The coefficient of concept significance score variation does not exceed 32%, and is 22% on average, which indicates that the set of scores is homogeneous, although significant by dispersion, particularly due to the large scale of the scores.

2.2. Concept characteristics

In order to enable the experts to consistently assess the concept system structure and the concepts' mutual influence, it is important to agree on the interpretation of the main ones.

Scientific performance was the main target factor in this study and was defined as the contribution of a professional or a group of R&D professionals in the country's GDP. However, this indicator is rather difficult to quantify, since there are many external effects (Prichina O.S., Orekhov V.D., Shchennikova E.S., 2017. pp. 77–81) of scientific work, which contribute to the profit of related organizations. At the level of expert evaluation, this indicator for an industry or other object can be measured by assessing scientific achievements in this field.

Often, scientific performance is measured using the indicator of the number of publications per million dollars of R&D expenditure based on the PPP (Labor Productivity in Russia and in the World, 2016, pp. 1–44). By this indicator, Russia is second only to France and Britain and is ahead of the US, Germany, and Japan. However, one cannot neglect the fact that this indicator is more appropriate for assessing research and less takes into account achievements in design and development, since it does not include patent activity into consideration. A more accurate assessment of the results of R&D professionals is possible if the overall parameter of papers published abroad and applications for patents classified as annual investments in R&D is considered. Relevant data (Russia and EU Member States, 2017, pp. 1–213) show that the number of publications indexed in WoS and Scopus, and patent applications filed in the country per billion dollars of GDP (PPP) in Russia per year is half of their number in developed European countries, which is due to the low level of investment in R&D. However, Russia is at the same level as certain developed countries by publication activity per million dollars of investment in R&D, although not at the highest one.

Education level. As noted above, it is a concept that has the highest influence on the efficiency of scientific work, since the contribution to GDP depends exponentially on the number of years of education – L (1). Russia is among the world leaders by the education level of the population. The share of citizens who have obtained vocational education between 25 and 64 years of age is 58% (Twelve Solutions for New Education, 2018, p. 9). On the other hand, according to (The Global Competitiveness Report 2017–2018, p. 248), the Higher Education and Professional Retraining parameter is estimated at 3.6 on a five-point scale, i.e. relatively low. One of the factors of this estimate is that professional retraining in the conditions of poor financing and high depreciation of equipment does not provide for sufficient training in operating modern high-performance equipment. This factor can only be controlled by encouraging highly-educated people to work in the R&D field.

Intelligence quotient (IQ). It is obvious that intelligence quotient is important for scientific work. The IQ of Nobel laureates is 136 on the average (Stepanov S.C., 2006, pp. 1–232). About 1% of the country's population have such a high IQ. However, high IQ is not a guarantee of success in life or science.

Self-control, will. There are a number of approaches to adequately characterize the influence of human intelligence on people's performance, with the concept of emotional intelligence worth noting in particular (D. Goleman, 1995). However, it is advisable to choose a concept more understandable for evaluation of scientific activity by experts: “self-control, will” (Muraven, M., Shmueli, D., Burkley, E, 2006 pp. 524–537), (Barabanov D.D., 2015, pp. 1–188).

Misconceptions in consciousness . This factor was isolated from the main list, since it is very difficult to evaluate what is in the unknown part of consciousness. Nevertheless, this concept is important for understanding the importance of critical thinking.

There are many misconceptions in human consciousness that arise for a variety of reasons. One of them is obsolete theories and incorrect interpretation of experiments. A person perceives information much faster than the time needed to verify it. Therefore, dubious facts often remain in the mind. The book *Economics* (McConnell C.R., Brue S.L., 2006, p. 12) provides a number of examples. Among them is the application of the properties of the particular to the general, in the course of which a true statement becomes invalid.

The above brief descriptions of the role of a number of important concepts in scientific activity demonstrate the relatively high complexity and ambiguity of their understanding. Therefore, they were iteratively discussed in the group of experts, as common stances were agreed.

2.3. Finalization of the concept list

Based on the experts' recommendations, we added a number of concepts. In particular, scientific performance and labor compensation were included in the block of individual factors. The following concepts were added in the block of critical thinking: innovative methods of thinking and teaching new knowledge and skills. A new group of factors associated with the impact of the external environment and R&D management at the organization level was also formed.

Further, in the course of the cognitive map formation, some concepts, for which it was difficult to find connections within the framework of this system, were excluded. Then, the experts were surveyed once again to determine the significance of the concepts and their level for Russia. The second survey used a 10-point scale with a smaller scoring step. The results of the survey, in accordance with the revised list (mathematical expectation M and standard deviation SM), are provided in Table 2.

Table 2. Significance of the revised list of concepts and its values for Russia

Group	No.	**Concepts**	Significance M	Level for Russia M	Significance S	Level for Russia S
Measurable concepts	1	Education level	8.3	7.4	0.5	0.8
	2	Intelligence quotient (IQ)	7.7	7.1	2.2	1.4
	3	Communication skills, connections	7.2	6.0	1.5	2.2
	4	Foreign language skills	7.0	5.0	1.5	1.8
	5	Scientific performance		5.8		1.1
	6	Labor compensation	7.3	4.0	2.2	1.2
	7	Computer support	8.2	6.3	1.0	1.3
Mental concepts	8	Self-control, will	8.1	6.0	1.8	1.8
	9	Teaching critical thinking	7.6	5.5	1.3	1.8
	10	Training in new knowledge and skills	7.3	6.1	1.3	1.4
	11	Innovative methods of thinking	7.4	5.6	1.2	1.5
	12	Ability to identify and solve problems	7.7	5.5	1.6	1.1
	13	Ability to think systematically	8.0	6.0	1.3	1.1
External influence	14	Financing and provision of resource	8.2	4.6	0.8	1.3
	15	Demand for scientific developments	8.4	4.6	0.9	1.4
	16	Strategic development programs	8.0	5.6	1.7	1.5
	17	R&D support system in the company	8.7	4.9	0.9	1.1
	18	Innovative business culture	7.0	4.9	1.6	1.5
Teamwork	19	Agreed common goal	7.3	5.7	1.7	1.7
	20	Psychological climate in the group	7.4	6.0	1.3	2.0
	21	Teamwork training	6.8	5.9	1.0	2.0
	22	Competence variety	7.6	6.5	1.4	1.8
		Average value	**7.7**	**5.7**	**1.4**	**1.5**

The survey results can be summarized as follows. The average significance score is 7.8, while for Russia it is 5.7 (an average level approximately). The highest significance score was given to the following concepts: R&D support system in the company (8.7), education level (8.3), demand for scientific developments (8.4). The lowest concepts according to the estimates were: teamwork training (6.8), innovative business culture (7.0) and foreign language skills (7.0). The score level for

Russia was by about two points lower than the significance, in general. The standard deviation was on average 1.5 points for both measured values and varied from 0.5 to 2.0. The variation factor for most concepts did not exceed 33%, which indicates that the set of scores is homogeneous. Among the parameter groups, “external impact” had the greatest significance and, at the same time, the lowest level for Russia.

2.4. Formation and assessment of the cognitive matrix

As a result of discussions, we built a cognitive matrix shown in Fig. 1 as quartiles (1 = 0.25, 2 = 0.5, 3 = 0.75).

Table 3. Cognitive matrix of scientific performance

	Concept, group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Education (years of study)				1	3	1		1														
2	Intelligence quotient (IQ)					1																	
3	Communication skills, connections					2																	
4	Foreign language skills			2																			1
5	Scientific performance						2							1			-2		1				
6	Labor compensation	3	1			1																	2
7	Computer support					2																	
8	Self-control, will					2														2			
9	Teaching critical thinking											2											
10	Innovative methods of thinking					1																	
11	Ability to identify and solve problems					2																	
12	Ability to think systematically					2																	
13	Financing and provision of resource					2	1									2	2						
14	Demand for scientific developments	2		1										3			2						
15	Strategic development programs														3								
16	Retraining of scientific personnel	1			1					2	1	1	2										1
17	R&D support system in the company						1	1									3						
18	Innovative business culture	1								1								2				1	
19	Agreed common goal					2													2				
20	Psychological climate in the group					1																	
21	Teamwork training			1																2	1		
22	Competence variety					2																	

An analysis of the influence consonance showed that it was equal to 72% on the average; i.e. quite high and, in general, the matrix was credible. The alpha-section of the influence consonance at 90% is shown in Figure 1.

However, the consonance is below 50% for a number of concepts, mainly in the mental block (teaching critical thinking, innovative methods of thinking, ability to identify and solve problems and think systematically, communicative skills and foreign languages skills). This is a consequence of the fact that connections that affect these concepts in terms of the impact of other concepts and the whole system are not numerous and strong enough.

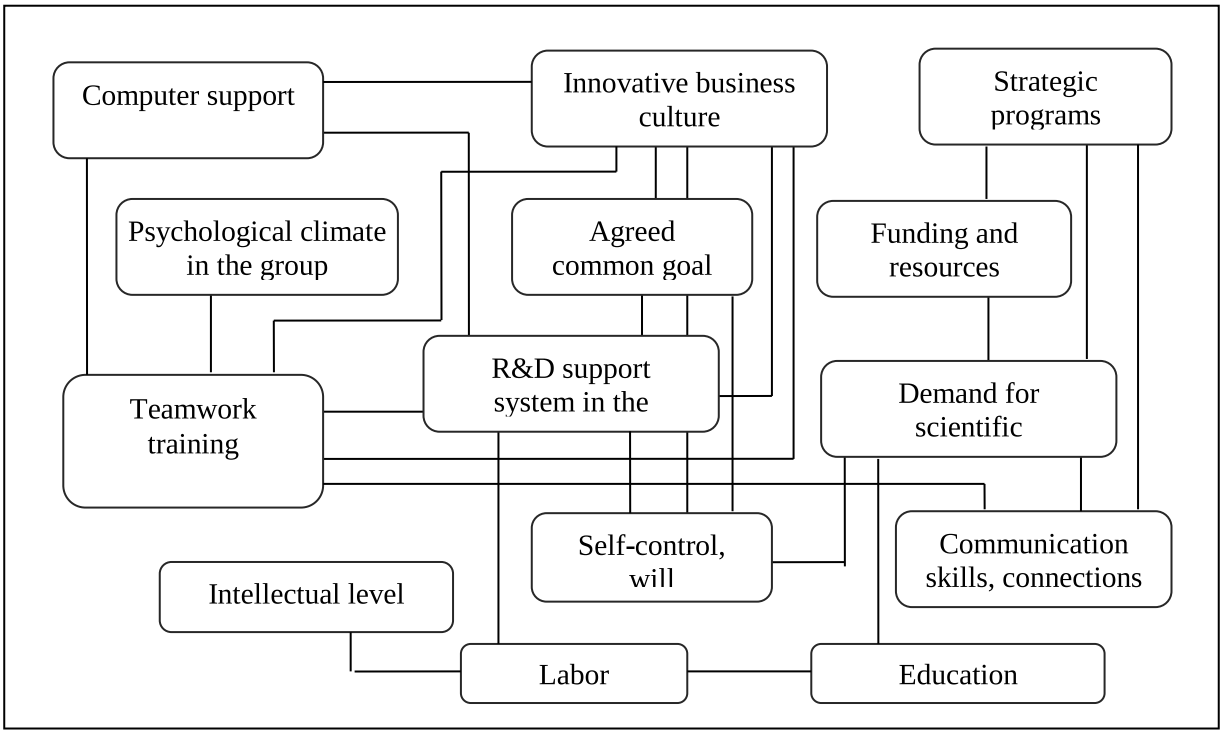

Figure 1. Alpha-section of the influence consonance at 90%

3. DISCUSSION

One of the objectives of this study was to reveal the influence of critical thinking and teamwork on scientific performance. And although certain positive results were achieved at the initial stage of the study, the problem was not solved completely. In particular, we are concerned with the fact that the influence consonance by some mental concepts is less than 50%. However, it can be noted that this phenomenon can also be observed in real life, since the implementation of mental methods to increase scientific performance is very inconsistent. They could be implemented through institutions, such as professional communities, although in Russia they are only beginning to develop (Prichina O.S., Orekhov V.D., Shchennikova E.S., 2017, pp. 46–51).

It should also be noted that an attempt to improve the accuracy of the experts' survey by introducing a ten-point scale led to the experts' complaints about the assessment complexity, as the concepts used were rather complex and intangible.

SUMMARY

In this study, we have formed a system of terms for the discussion of the relevant subject: Scientific Teams' Performance Management, which includes issues of critical thinking, teamwork, external environment, etc.

We involved a group of experts to assess the concepts' significance and their level for Russia and formed a fuzzy cognitive matrix of the connections of the system concepts.

The matrix was processed with DSS and it was shown that the influence consonance was equal to 72% on the average, i.e. was quite high and, in general, the matrix is credible. We identified the concepts with a low consonance and low influence of the system on the concept, which mainly belong to the group of mental concepts.

The obtained assessment information characterizing the revealed relationships of the system enables decision-makers to formulate recommendations on the research activity system management.

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