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Abstract. The article describes the problem of awakening the cognitive activity of students, arising due to revolutionary transformations in teaching technologies. It shows the need to study the factors that affect cognitive activity and assesses the information content of those factors. Based on the method of pair comparisons, a technology for ranking the factors affecting cognitive activity has been developed. A mathematical model of the formation and processing of expert assessment results and an example of calculations are given, and the feasibility of including the subsystem for evaluating factors affecting cognitive activity in the computer control system of the university is shown.
The article shows how the results of assessment can be used in developing strategies for improving the educational process at the university, as well as the results of improving the quality of the educational process after the introduction of a computer-based e-learning system modernized using the proposed method (on the example of the Sumy National Agrarian University).

Keywords: cognitive independence, e-learning, human factor, lifelong learning, distance learning, learning management system, influencing factor

1 Introduction

The current revolution in education [1-2], the e-learning technology that has received a surge (also due to the problem of COVID-19) [3-4], as well as the concept of lifelong learning [5-6] exacerbated the problems of

- The quality of e-learning environment [7-8]
- Adaptive learning [9-10]
- Activation of cognitive independence [11-12].

In the complex of problems of pedagogy of electronic society, the problem of such a personality quality as “cognitive independence” comes out on top [1,13].

2 Problem Statement

Various aspects of the problems of cognitive independence are considered in a huge number of scientific studies, including [13-14]. General issues [15-16], the structure of cognitive independence [17], various methods of activating cognitive independence [15-18], etc. are being studied. However, in general terms, the task of optimizing cognitive independence in the conditions of the modern stage of e-learning throughout life, unfortunately, has not been solved.

There is not even a single universally accepted definition for cognitive independence.

In this study, we use the definition of [19]: “Cognitive independence of students is an integrative quality of the personality, based on cognitive activity associated with the initiative and the search for various ways to solve educational and cognitive problems without the participation of a teacher (the teacher prepares a system of tasks), which ensures self-development of personality.

Identification of factors of cognitive independence is the main prerequisite (first stage) of activation of cognitive independence, as shown in [14-15].

A significant number of cognitive independence factors have been identified [19].

The problem is that the degree of manifestation of those factors varies depending on the particular educational environment and tends to change rapidly [1, 13, 14].

The question of the degree of manifestation of each factor in the general structure of cognitive independence is of interest to many researchers [14-19]. Unfortunately, there is no universal method for solving this problem.

In this regard, we define the purpose of this work as follows:

“Develop a computer-based method for assessing the information content of cognitive independence factors and their ranking (in terms of pedagogical value for managing cognitive independence in the system of lifelong learning), using the structure of cognitive independence as an explicit concept.”

3 Results

3.1 Method for assessing the information content of cognitive independence factors

The information content of a factor is the ability of this factor to contain information about the degree of its influence on cognitive independence.

There are various approaches to assessing the information content of the factors. In our case, we are dealing with virtual reality, because cognitive self-sufficiency is a personality trait that we construct by the method of explication and ascribe to trainees, and the factor is a component of this property. Therefore, as a measure of the information content, it is not correct to use measures based on objective probabilities of

occurrence of combinations of factors and phenomena. For the same reasons, we cannot use instrumental and imitation methods for assessing skills [19] to identify the degree of influence of any factor on the development of cognitive independence.

Therefore, expert methods based on subjective assessments of experts are the most suitable methods for this purpose.

Among the expert methods used in pedagogical research, we distinguish the following ones: the method of rank order, the method of predetermined scoring, the method of free scoring, the method of coefficient estimation of the level of assimilation, and the method of pair comparisons [19-21].

Our experiments with teachers, who were invited to use various technologies of expert assessment, showed that the method of pair comparisons can be considered the most convenient.

In this regard, the following assessment technology has been developed:

Stage 1.

Formation of the questionnaire. To determine the degree of influence of factors on the development of cognitive independence of a student, we form a special questionnaire in which expert educators are invited to evaluate the degree of joint manifestation of the main characteristics (factors) of cognitive independence. To do this, they fill out a table to record the characteristics (factors) of cognitive independence

- a) from top to bottom in the first column of the table
- b) from right to left in the same order.

The compiled table is scanned from left to right: each column element is compared with each row element.

If, according to the expert, the element located in the left column of the table is less common than the element placed in the top row, then "1" is written in the cell at the intersection of the column and row. If the element located in the top row of the table is more common than in the left column, then "0" is put in the numerator. In the case of equal manifestation frequencies, a value of 0.5 is set in the cell. The experts do not fill out last two columns for R and P.

Stage 2.

Processing questionnaires. As a result of filling out the questionnaire by experts, one can calculate the degree of manifestation of the components of cognitive independence. Further, the obtained information is processed as follows: first, line-by-line summation of the contents of the cells is performed. The result of this summation is the rank R of each factor in the structure of cognitive independence. It is written to the corresponding "rank R" column of the table. The factor with the highest rank is assigned a degree equal to 1.

Then, the degree of manifestation P_i of each factor is calculated by the formula:

$$P_i = \frac{P_{max} * R_i}{R_{max}}, \qquad (1)$$

where P_{max} =1 - the degree of manifestation of the factor that has the highest rank;

R_i is the rank of the factor;

R_{max} is the highest rank.

The results are entered in the column "Degree of *P* manifestation". This is how all data provided by each expert is processed.

Then a table is filled in, where the results of the questionnaires are summarized. The results of calculating the degrees of P_{ni} from each questionnaire of the *n*-th expert for each *i*-th factor are transferred to this table, i.e., column P_1, is filled in for the 1st expert, column P_2 - for the 2nd expert, …, and column P_n - for the *n*-th expert.

The averaged values of the degrees of manifestation of factors in the structure of cognitive independence are calculated based on the obtained P_i data:

$$P_{i,av} = \frac{\sum_{j=1}^{n} P_{ij}}{n}, \qquad (2)$$

where *n* – the number of experts, *j* – the expert's number; *i* -factor number. These values serve as a measure of the informative value of the factor.

Further, the variance S_i of expert estimates for each factor is determined, which is calculated by the formula (for a small sample, an unbiased variance estimate is used):

$$S_i = \sqrt{\frac{\sum_{j=1}^{n} \left(P_{i,j} - P_{i,av}\right)^2}{n-1}}, \qquad (3)$$

where *n* – the number of experts, $P_{i,j}$ – the degree of manifestation of the *i*-th factor in the structure of cognitive independence according to the *j*-th expert. The value of *n-1* indicates the number of degrees of freedom.

Then, a confidence interval of values for each component of cognitive independence is determined by the formulas:

$$\nu_i = t_\varphi * \frac{S_i}{\sqrt{n}}; \quad \mathrm{P_i^u} = P_{i,av} + \nu_i; \quad \mathrm{P_i^l} = P_{i,av} - \nu_i, \quad (4)$$

where ν_i is the confidence interval; t_φ is the confidence probability; P_i^u (P_i^l) - the upper (lower) confidence boundary of the values of information content of factors of cognitive independence.

3.2 Implementation of a method for assessing the information content of cognitive independence factors

The described model is implemented in the adaptive e-learning system that we have developed [10], and as part of the manager's special agent [21], it can be integrated into any training management system.

3.3 An example of assessing the information content of cognitive independence factors

Consider an example developed as an experiment in the Center of Distance Education of the Sumy National Agrarian University, when studying the cognitive independence of students (economic specialties) who are trained at the Department of Cybernetics and Informatics (Department Head - Svetlana Agadzhanova).

The number of experts is 16 (teachers of the department and employees of the Distance Education Center).

The working group identified the following main factors, affecting cognitive independence (in the study of the disciplines of the computer and cybernetic cycle):

1. The need and desire to acquire knowledge and methods of activity
2. Cognitive motive and interest
3. Interest in the results of their independent cognitive activities
4. Interest in a future profession
5. Initiative
6. Basic knowledge (owned by the individual)
7. Basic skills, computer skills and previously learned software tools
8. Acquired knowledge of the studied disciplines of the computer cycle
9. Acquired skills in the studied disciplines of the computer cycle, computer skills and learned software
10. Use of scientific and methodological literature, communications, the Internet
11. Attentiveness
12. Strong-willed efforts
13. Purposefulness
14. Persistance
15. Contact with the teacher during the performance of independent cognitive activities in order to obtain information
16. Contact with other students during the performance of independent cognitive activities in order to obtain information
17. The ability to set and achieve goals of cognitive activities
18. The ability to plan their cognitive activities
19. The ability to assess their potential in the performance of cognitive activities
20. The ability to evaluate the results of their cognitive activities.

The calculation results, ranked by the upper confidence interval, are presented in Table 1.

In a study with a reliability level of 95% (for all components) and a number of degrees of freedom equal to 16, the confidence probability (Student's coefficient) is t_{φ}= 2.1314. Table 1 and Fig. 1 show the results of calculating the confidence intervals of the information conent for each of the 20 factors of cognitive independence.

If we rank the values of the upper boundaries of confidence intervals, we can talk about the most informative factors of cognitive independence.

Table 1. The ranking results of the factors that form the cognitive independence of students (Sumy National Agrarian University, Ukraine)

Parameter No.	P_{cp}	S_i	n_i	$P_i^{в}$	$P_i^{н}$	$P_i^{в}$ *rank*
16	0.6929	0.3413	0.1892	0.8821	0.5036	1
8	0.7312	0.1435	0.0796	0.8108	0.6516	2
20	0.6626	0.2429	0.1347	0.7973	0.5279	3
15	0.6276	0.2927	0.1623	0.79	0.4653	4
9	0.7135	0.1136	0.063	0.7765	0.6505	5

Parameter No.	P_{cp}	S_i	n_i	$P_i^в$	$P_i^н$	$P_i^в$ rank
6	0.663	0.1126	0.0625	0.7255	0.6006	6
7	0.6251	0.1293	0.0717	0.6968	0.5534	7
19	0.514	0.3156	0.175	0.689	0.339	8
12	0.5855	0.148	0.082	0.6675	0.5034	9
10	0.6273	0.0661	0.0367	0.664	0.5906	10
14	0.4967	0.1912	0.106	0.6027	0.3906	11
11	0.5594	0.0658	0.0365	0.5958	0.5229	12
18	0.4512	0.2475	0.1372	0.5885	0.314	13
13	0.5063	0.1373	0.0761	0.5824	0.4302	14
4	0.5455	0.0418	0.0232	0.5686	0.5223	15
1	0.5142	0.0623	0.0345	0.5488	0.4797	16
3	0.4576	0.1272	0.0706	0.5281	0.387	17
2	0.4965	0.0257	0.0143	0.5107	0.4822	18
5	0.4407	0.0691	0.0383	0.479	0.4024	19
17	0.3684	0.1662	0.0922	0.4605	0.2762	20

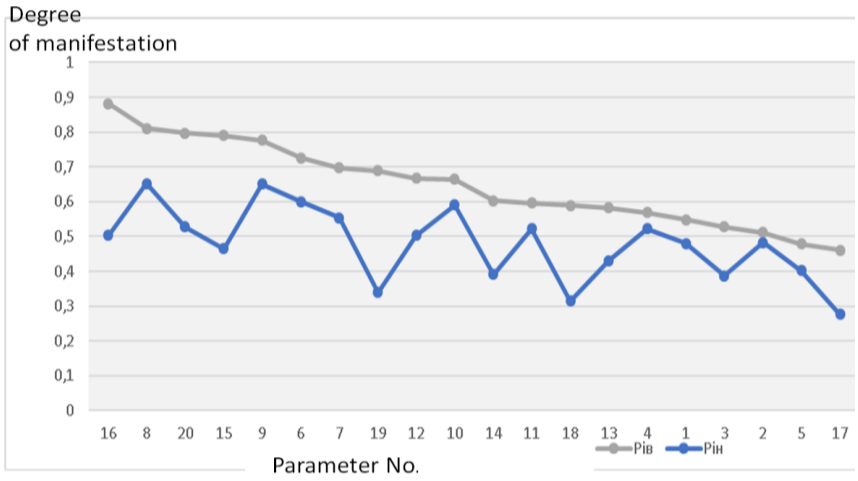

Fig. 1. Confidence intervals of the degree of manifestation of personal qualities in the structure of cognitive independence ($P_{iв}$, $P_{iн}$ - upper and lower confidence limits)

3.4 Improving educational technologies using the results of assessment of the information content of cognitive independence factors. An example.

Using the results of assessment of factors allows each university to find those “pain points" that need special attention when improving educational technologies [10, 22, 23].

Based on the result of the experiment described above, a special technology was developed (information environment for e-learning) with special advanced features [10, 21], including:

• Communication between students in the process of independent work (factor 16, rating 1)

• Self-control of the learning process (factor 20, rating 3)

• Prompt communication with the teacher (factor 15, rating 4)

• Other.

The use of a new educational information environment in the groups of faculties of management, veterinary and agronomy of the Sumy National Agrarian University (data obtained as a result of the experiment [10, 21, 24]) allowed them

-To increase significantly academic performance from 72.3 to 81.4 (by 100 point scale)

-To decrease the frequency of refusals from independent work of students using the e-learning environment from 24.8% to 7.3%.

4 Conclusion

Cognitive independence is an integrative quality of a person, based on cognitive activity associated with the initiative and the search for various ways to solve educational and cognitive tasks, ensuring self-development of a person.

The technology of questioning and processing the opinions of experts (teachers), based on the method of pair comparisons, is a convenient means of identifying the degree of influence of various factors.

Due to the rapid change in teaching technologies and the psychological characteristics of students, an assessment of the degree of influence of factors on cognitive independence should be carried out regularly.

Embedding a subsystem for assessing the influence of factors in the learning management system is a convenient means for assessing.

Assessing the importance of factors affecting cognitive independence is a necessary step in improving the educational process, including the electronic educational environment.

The experiments carried out confirmed the constructiveness of the method and the possibility of significant improvements in the quality of the educational process, based on a systematic study of factors affecting cognitive independence.

The authors dedicate this article to the memory of their teacher, Doctor of Technical Sciences, Professor Akiva Tovievich Asherov (1938-2011), who first formulated the ideas that formed the basis of the study.

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