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# DRAWING UP TESTS WITH USE OF A METHOD OF PLANNING OF FACTORIAL EXPERIMENTS ON THE SUBJECT "THE RULES OF ELEMENTS OF THE BLOCK DIAGRAM"

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***Abstract***

*The designed two-factor test questions based on the allocated microknowledge reflecting bases of understanding and elementary knowledge of one of subjects of the theory of automatic control are given. They are intend for intermediate examination. The new technology of drawing up tests is support by new technology of their processing. Their advantages are illustrate by an example of statistical processing. Bar graphs, both average estimates of answers, and their confidential deviations are constructed. They show both the level of knowledge of all test, and degree of confidence of this knowledge.*

***Key words:*** *testing, microknowledge, factors of knowledge, subject factors, test factors, test question, test answer, variability, statistics of level of knowledge, statistics of unevenness of knowledge.*

## Introduction

Due to a profound reform of the entire system of higher education in Russia today more and more attention is pay to the evaluation and certification of students' knowledge.

The main difficulty in the implementation of test methods in educational institutions is the lack of adequate training of teachers in terms of test design and application as well as the opportunity to master these techniques. In connection with this one problem becomes very urgent - the problem of formalization of building the test tasks allowing to keep high test evaluation capacity, at the same time facilitating the test development for average teachers.

Both the fundamental studies [1-4] and works devoted to the practical implementation of different components [5-6] offer new to a large extent technique of test design and conduct involving two-factor and three-factor two-level tests.

## Problem Statement

One of the character features of the test task is the number of valid responses from a variety of those offered. When only one answer to a question is permit, the person tested has a rating expressed in the degree of full knowledge. This increases the probability of guessing the correct answer so it is impossible to have an accurate assessment of the test results.

Thus, an effective evaluation of training in the discipline studied the subject with uncertain knowledge requires multiple choice answers which he will consider close to correct ones. This does not exclude the possibility of selecting one answer.

In this case, the assessment of knowledge is form as a sample of meaningfulness estimates of the answers given by the tested. This approach makes it possible to obtain an estimate of the degree of randomness for answer choice which characterizes the uncertainty of the tested' knowledge. This is because there is an opportunity to assess the closeness of the content of the selected test

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responses. Too diverse estimated responses will indicate the uncertainty of knowledge and the homogenous - the proximity of the subject to true knowledge.

**The essence of the proposed method of solving the problem**

The process of a test question development is regard as the construction of a line including ***n*** character variables denoting different micro knowledge [2]. According to the previously introduced paradigm, each micro knowledge can be compare with two options: the right - «Yes» and the wrong - «No». Then the set of possible variants of answers to a test question becomes similar to the matrix of planning a two-level multifactor experiment, a positive response - «Yes» is replaced with +1 and a negative response - «No» with -1. Thus, by varying answers to micro knowledge on two levels it is possible to get a set of line-answers to the full test question, which realizes all their possible combinations by analogy with a full factorial experiment. If the number of micro knowledge ***n*** is, selected one can find the number of different complete answers by the formula:

$$N = 2^k, \qquad (1)$$

where $N$ is the number of experiments, $k$ – the number of factors, 2- the number of levels.

**Examples of implementation of factor-based approach to test constructing**

As an example, we will consider the procedure of generating a test question on the topic « The rules of elements of the block diagram" of the subsection «Linear models of control systems" of the discipline Theory of automatic control.

Let us choose the following characteristics of dynamic links as the three assessed factors of knowledge of the tested' evaluation: the transfer rule of the adder through the link during signal propagation and transfer rule of the adder via link against the direction of propagation of the signal:

It is necessary to form the wording of the test question including the sum total of the factor knowledge selected. We will apply the principle of maximum short [1] wording of factor knowledge to minimize the probability of random errors generated by the human factor - the natural excitement of the tested.

The question wording. According to the presented in the figure the block diagram, determine the links that are add to the branches of the summing node when it is transfer via dynamic links:

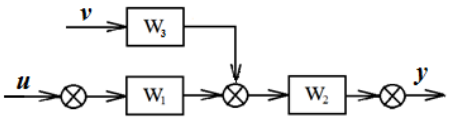
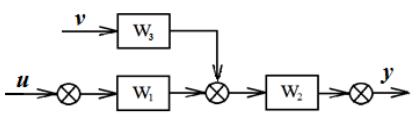



Figure 1. –Block diagram.

Correct and incorrect responses on the factors of knowledge are summarize in table 1.

Table 1.

Correct and incorrect responses on the factors

| № TQ | ***Block diagram***  | ***Formulation of a test question:*** According to the presented in the figure the block diagram, determine the links that are add to the branches of the summing node when it is transfer via dynamic links. |
|---|---|---|
| 1. | **Knowledge factors:** | **Versions of the wrong answers:** |
| | At transfer of the summarizing knot through a link on the course of distribution of a signal to a | At transfer of the summarizing knot on the course of distribution of a signal to a branch of the adder the link is added $W_1$. |

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| | | |
|---|---|---|
| | branch of the adder the link is added $W_2$. | At transfer of the summarizing knot on the course of distribution of a signal to a branch of the adder the link is added $1/W_1$. |
| | | At transfer of the summarizing knot on the course of distribution of a signal to a branch of the adder the link is added $1/W_2$. |
| | At transfer of the summarizing knot through a link against the course of distribution of a signal to a branch the link is added $1/W_1$. | At transfer of the summarizing knot through a link against the course of distribution of a signal to a branch the link is added $W_1$. |
| | | At transfer of the summarizing knot through a link against the course of distribution of a signal to a branch the link is added $1/W_2$. |
| | | At transfer of the summarizing knot through a link against the course of distribution of a signal to a branch the link is added $W_2$. |

**The result of the test**

Based on the methodology of constructing multifactor two-level tests, test assignments were design and tests were conduct to reveal the knowledge of students in the discipline Theory of automatic control. Each subject was given 5 different test questions including two factors of knowledge. Table 2 shows the results of testing using three-factor test tasks.

During testing the average scores and the degree of uncertainty of knowledge was estimate to each $q$ test question and to the test as a whole. The results of statistical processing of the test and calculation of average evaluations of knowledge to each test question are show in the Table 2.

The table uses the following notation:

- $(e_i)_q$ - assessment of the selected by the tested $q$-th line of the test question;
- $\overline{e_q}$ - average evaluation of the level of knowledge of a specific $q$-th test question;
- $\sigma^2_{(e)q}$ - variance of the estimates of responses to the $q$-th test question;
- $\sigma_{(e)q}$ - value of the standard deviation, which corresponds to the degree of uncertainty of knowledge of the subject to the test question;
- $\overline{e_j}$ - total score of knowledge on the entire sample of tests of the j-th subject;
- $\sigma_j^2$ and $\sigma_j$ - variance of answer confidence on the test and the value of the standard deviation of the j-th subject.

The assessment of the level of knowledge to the $q$-th test question is calculated as the average of estimates of lines of test questions that the subject limited himself to:

$$\overline{e_q} = \sum_{i=1}^{n} (e_i)_q / n \tag{2}$$

where $n$ - is the number of selected lines-answers in the $q$-th test task $(n \le 2)$.

The degree of uncertainty of the subject about the answer to the $q$-th test task is estimated as the variance of answer estimates:

$$\sigma^2_{(e)_q} = \sum_{i=1}^{n} ((e_i)_q - \overline{e_q})^2 / (n-1) \tag{3}$$

or the corresponding standard deviation:

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$$\sigma_{(e)q} = \sqrt{\sigma^2_{(e)\,q}} \tag{4}$$

The assessment of the level of knowledge of the j-th subject on the test passed is calculate as the average number of votes for all the test questions:

$$\overline{e_j} = \sum_{i=1}^{n} \overline{e}_q / n \tag{5}$$

The degree of confidence of the j-th subject on the test passed is calculate as the average variance of answer confidence to all test questions:

$$\sigma_j^2 = \sum_{i=1}^{n} \sigma^2_{(e)q} \setminus q_i \tag{6}$$

or the corresponding value of RMS:

$$\sigma_j = \sqrt{\sigma_j^2} \ . \tag{7}$$

Thus, the data obtained after statistical processing of the factorial test rather versatility are also representative as are supported by all factors of knowledge entering all test questions [3-5]. Along with the general assessment of a share, traditional for testing procedure, of the acquired material - $\overline{e_j}$ and the differentiated assessment well and badly acquired his elements - $\overline{e}_{ij}$ the factorial structure of the test allows to estimate additional characteristics of knowledge.

In the table 2 questions in which tested have chosen two lines of answers are highlighted with color.

Table 2.

The test results and the calculation of the average estimates of knowledge to test questions.

| № | $(e_i)_{qs}$ | The number of subject (j) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Test task 1 | $(e_1)_{13}$ | 0,5 | 1 | 1 | 1 | 0 | 1 | 0 | 0,5 | 0,5 | 1 | 1 | 1 |
| | $(e_2)_{13}$ | 0,5 | 1 | 1 | 1 | 0,5 | 1 | 0 | 0,5 | 0,5 | 1 | 1 | 1 |
| | $\overline{e_{13}}$ | 0,5 | 1 | 1 | 1 | 0,25 | 1 | 0 | 0,5 | 0,5 | 1 | 1 | 1 |
| | $\sigma_{(e)13}$ | 0 | 0 | 0 | 0 | 0,35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Test task 2 | $(e_1)_{23}$ | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 0,5 | 0,5 | 0,5 | 1 | 1 | 0,5 |
| | $(e_2)_{23}$ | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 0,5 | 0,5 | 0,5 | 0,5 | 1 | 0,5 |
| | $\overline{e_{23}}$ | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 0,5 | 0,5 | 0,5 | 0,75 | 1 | 0,5 |
| | $\sigma_{(e)23}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,35 | 0 | 0 |
| Test task 3 | $(e_1)_{33}$ | 0,5 | 0,5 | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 1 | 0,5 | 1 | 1 |
| | $(e_2)_{33}$ | 0,5 | 0,5 | 0,5 | 1 | 0,5 | 0,5 | 0,5 | 1 | 1 | 0,5 | 1 | 1 |
| | $\overline{e_{33}}$ | 0,5 | 0,5 | 0,75 | 1 | 0,5 | 0,75 | 0,5 | 1 | 1 | 0,5 | 1 | 1 |
| | $\sigma_{(e)33}$ | 0 | 0 | 0,35 | 0 | 0 | 0,35 | 0 | 0 | 0 | 0 | 0 | 0 |
| Test task 4 | $(e_1)_{43}$ | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 0 | 1 | 1 | 0,5 | 0,5 | 1 |
| | $(e_2)_{43}$ | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 1 | 1 | 1 | 0,5 | 0,5 | 1 |
| | $\overline{e_{43}}$ | 1 | 1 | 0,5 | 1 | 0,5 | 1 | 0,5 | 1 | 1 | 0,5 | 0,5 | 1 |
| | $\sigma_{(e)43}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0,7 | 0 | 0 | 0 | 0 | 0 |
| Test task 5 | $(e_1)_{53}$ | 0,5 | 0,5 | 1 | 1 | 1 | 1 | 0,5 | 0 | 0,5 | 0,5 | 1 | 1 |
| | $(e_2)_{53}$ | 0,5 | 0,5 | 1 | 1 | 0,5 | 1 | 0,5 | 0 | 0,5 | 0,5 | 1 | 1 |
| | $\overline{e_{53}}$ | 0,5 | 0,5 | 1 | 1 | 0,75 | 1 | 0,5 | 0 | 0,5 | 0,5 | 1 | 1 |
| | $\sigma_{(e)53}$ | 0 | 0 | 0 | 0 | 0,35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\overline{e_{js}}$ | 0,7 | 0,8 | 0,75 | 1 | 0,5 | 0,95 | 0,4 | 0,6 | 0,7 | 0,65 | 0,9 | 0,9 |
| $\sigma_{js}$ | 0 | 0 | 0,15 | 0 | 0,22 | 0,15 | 0,28 | 0 | 0 | 0,15 | 0 | 0 |

The results of the test were constructed bar graphs presented in figure 2.

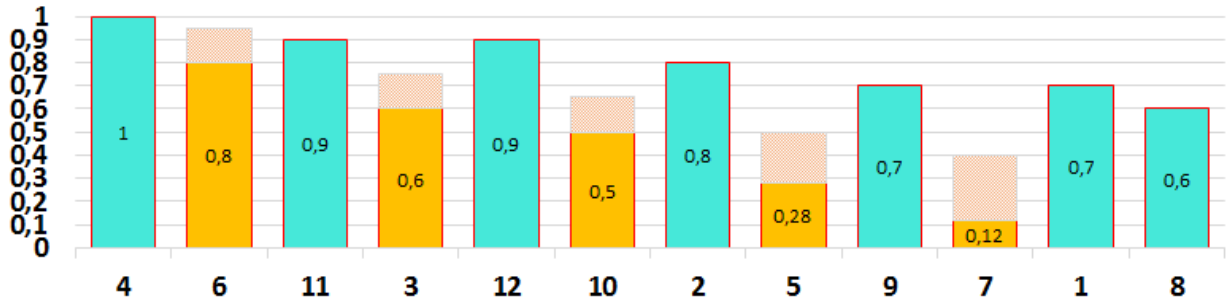


Figure 2. – Bar graphs

**Conclusions**

The analysis of the obtained statistical results presented in Table 2 indicates the uneven character of variances.

For example, the subjects who limited themselves to one line of answer in each test tasks have a uniform variance and a corresponding value of RMS equaling zero for all test tasks and for the test as a whole. Which reflects the confidence of partial knowledge (subject's No. 11, 12, 2, 9, 1, 8 who opted semi-correct answers with different ratings) or full knowledge (subject No. 4 who selected all correct answers).

When investigating variances evaluated by different types of test tasks the greatest interest is take in non-uniform variances. The analysis of which may indicate the uncertainty of knowledge of the subjects in certain test tasks (for example, the subject No. 5 selected two lines of answers in the test task 1 and 5) as well as the degree of confidence in the assessment of knowledge of the test passed.

The heterogeneity of variances of the tests composed indicates uneven mastering of the discipline topic because the subject mastered some of the factors of knowledge and other factors of knowledge remained unclear.

The examined examples demonstrate a good level of formalization and convenience of test constructing based on the method of multifactor planning of two-level experiments. In addition, the evaluation of the test results is well-formalized increasing its objectivity.

An important innovation is the assumption of a peculiar «vagueness» of the answer to test question and generated by it two-parameter test score: the assessment of incomplete knowledge and the degree of certainty of that knowledge.

The results of tests using two-factor and three-factor test tasks established the role of "factor" nature of the test that affects the ranking of subjects with uncertain knowledge.

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**References**

1. Obuhova E.N. The research of the efficiency of the factorial knowledge and methods of designing factor tests. Computer Sciences and Telecommunications. 2016. №1(47). P. 3-7.
2. Nejdorf R.A. The algorithm for calculating and assessing the results of factor test evaluation / R.A. Nejdorf, E.N. Obuhova // Scientific Review. -2015 №2 - P. 45-52.
3. Nejdorf, R.A. Methodology of testing organization based on scheduling algorithms and processing of two-level multiple-factor experiments / R.A. Nejdorf, E.N. Obuhova // News of the Don State Technical University. – 2014. T. 14. №2. p.77. P.110-120.
4. Obuhova E.N. Calculation of estimates of factorial and test selection of knowledge of students. Mathematical Methods in Engineering and Technology - MMTT-28: Compilation of works of the XXVIII Intern. scientific. conf. / SSTU. - Saratov, 2015. №3(73) - P. 80-83.
5. Nejdorf, R.A. Features of use of factorial test system of an assessment of knowledge in educational process/ R.A. Nejdorf, E.N. Obuhova // Mathematical Methods in Engineering and Technology - MMTT-28: Compilation of works of the XXVIII Intern. scientific. conf. / SSTU. - Saratov, 2015. №3(73) P. 71-75.
6. Obuhova E.N. The analysis of results of testing of knowledge of students of discipline "The theory of automatic control" with use of multiple-factor test tasks. In the world of scientific discoveries. 2015. № № 8 (68). P. 146-161.

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