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Estimation of the Level of Cognitive Development of a Preschool Child Using the System of Situations with Mathematical Contents

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Cognitive development of personality can be considered as one of the key directions of preschool education presented in the world practice, where preschool programs are educational ones, and preschool education is the first level of the general education. Thereby the purpose of the research is to create a model of reliable estimation of cognitive development of a preschool child by means of the system of situations, including identification of the average level for chronological age. Thus the leading technology is modeling the systems of open-type tasks of mathematical contents and the system analysis of big selections of experimental data based on the two-point scale of four parameters: optimality of the ideas offered by children; efficiency of the reasoning given by them; originality of their answer and level of decision development. As a result of the pilot study conducted in 2015 on selection of 3,800 preschool children, it was succeeded to approve the offered technology of estimation and to generalize results in the form of the integrated assessment of relative character – coefficient of cognitive development level. Mathematical-statistical processing of the results of the research allows to prove uniformity of experimental selection and to specify the level of cognitive development with a reliable accuracy of normal distribution for each age group of the preschool child basing on calculation of samples quartiles that in turn can define the further program of individual development of a child providing his transition to higher level of the general education and consequently, higher quality of education.

Keywords: assessment of quality of education, preschool education, cognitive development, open-type tasks, preschool child.

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INTRODUCTION

Relevance of research

Improvement of control and management of education quality becomes one of the directions of modernization of the system of the Russian education. Thee priority directions of development of the educational system of the Russian Federation approved by the government note that it is necessary to create national system of assessment of educational quality received by the citizen (Government of the Russian Federation, 2008).

The essential step for modernization of preschool education is introduction of the Federal State Educational Standard of Preschool Education – FSES PE (Ministry of Education and Science of the Russian Federation, 2013). To ensure FSES PE introduction to the designated directions, there is a need of carrying out actions for creation of analytical ensuring of FSES PE realization (Ministry of Education and Science of the Russian Federation, 2014). On the one hand, the taken measures for development of analytical materials of FSES PE realization do not contain the ready diagnostic tools allowing to estimate quality of results, which learners of educational programs of preschool education master. On the other hand, an approximate main educational program of preschool education (Federal educational-methodological association on the general education, 2015) and author's educational programs of preschool education define a variable educational field, which, without a backbone approach, will provide a number of problems on creation the uniform educational space regulated by the purpose of modernization of the educational system in Russia (Government of the Russian Federation, 2013).

The educational standard of preschool education

The solution of the designated problems can consist in development of the all-Russian system of quality assessment of preschool education in the directions of development and education of children, according to p. 2.6 FSES PE (Ministry of Education and Science of the Russian Federation, 2013): social communicatively, cognitive, speech, art-esthetically and physical development.

Let's notice that among others, cognitive development can be considered as one of the key directions, which make preschool programs educational ones, and preschool education – the first level of the general education.

According to FSES PE, "cognitive development assumes … formation of cognitive actions, consciousness; imagination and creative activity; primary ideas about self, other people, objects of the world around, t properties and relations of world's objects …" (Ministry of Education and Science of the Russian Federation, 2013).

Thus, the all-Russian system of assessment of quality of preschool education in directions have to be originally constructed on the basis of diagnostics, capable to estimate the level of cognitive development, not attached to the educational program chosen by a kindergarten, with uniform criteria base for all subjects of the educational system.

MATERIALS AND METHODS

Research methods

In the course of the research the following methods were used: analysis of normative documents, psychological-pedagogic and methodological literature, products of educational activity, method of mental experiment, forecasting, systematization and generalization of facts and concepts, modeling, design, method

of expert evaluations, analysis of results of educational activity, analysis and synthesis of experience of application of open-type tasks with mathematical contents, diagnostic techniques, pedagogic experiment.

Experimental base of research

Skilled and experimental work was carried out by means of approbation of the system consisting of all-intellectual test and open-type tasks with mathematical contents through participation of 4–7 year-old preschool children in the heuristic competition "Owlet" (there were 3781 preschool-age participants in 2015). It was offered to participants to execute competitive option of work according to age. For a convenient statement of the results of the research, further the paper describes average total results of 4–5 and 6–7 year-old children.

Preschool children of all age groups (corresponding to preschool education) from various regions of the Russian Federation and certain neighboring countries were involved in skilled and experimental work.

Research stages

Research was conducted in three stages:

– The first (preparatory) stage analyses the current state of the studied problem in pedagogical theory and practice; develops the program of research technique;

– The second (basic) stage develops and introduces the systems consisting of all-intellectual tests and open-type tasks with mathematical contents; analyzes big selections of experimental data; carries out skilled and experimental work to check efficiency of the technique of assessment of cognitive development level of a preschool child;

– The third (final) stage systematizes, judges and generalizes the results the research; specifies theoretical conclusions; processes and registers the received results of the research.

RESULTS

Problem of estimation of cognitive development level

The special situations, which are not reduced to application of any subject knowledge are necessary to estimate the results. In our opinion, such situations can be open-type tasks, which provide possibility of application of standard knowledge in non-standard situation (Gorev & Utemov, 2011; Yarullin, Bushmeleva & Tsyrkun, 2015; Gabdrakhmanova, Khuziakhmetov & Yesnazarova, 2015; Sibgatova et al., 2015; Sibgatova et al., 2016).

Estimation of solutions of two open-type tasks and all-intellectual test taking into account the requirement of FSES PE can become a quantitative index of formation of cognitive development level. It is possible to consider the accuracy of estimation of cognitive development level of a child only when he solves carefully picked up system of such tasks. Then as the total level of icognitive development it is possible to consider the average total point following the results of their solution (Gorev & Utemov, 2014; Khuziakhmetov, Ladoshkin & Esnazarova, 2015; Nasibullov, Konysheva & Ignatovich, 2015; Zaitseva, 2013).

Open-type tasks as an instrument of estimation of cognitive development level of a preschool child

Let's address to the tasks providing possibility of application of standard knowledge in a non-standard situation. When performing such tasks, a pupil can show ability to logical and abstract thinking, i.e. ability to classify, generalize and draw analogies, predict result, applying intuition, imagination. Moreover, tasks promote formation of integrated meta-subject (inter-subject) quality and they are open-type tasks (Figure 1).

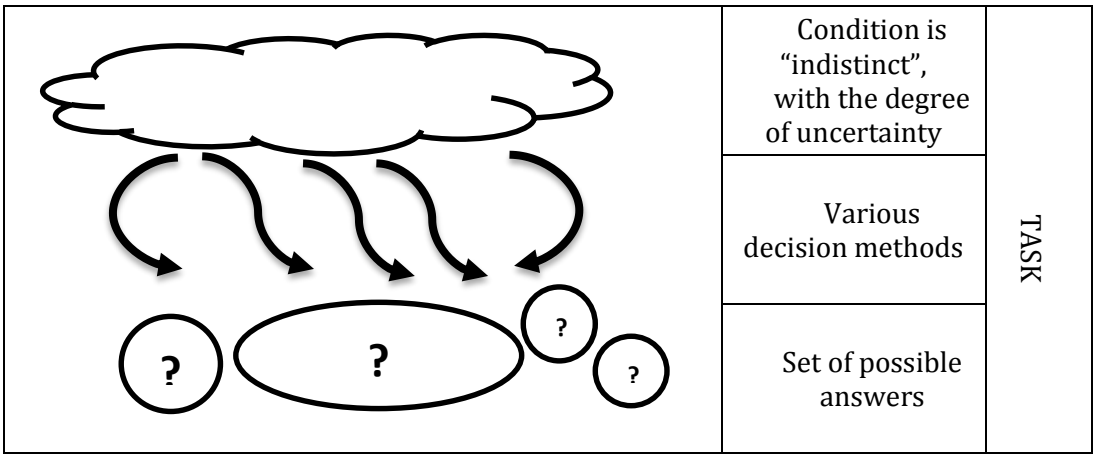

Figure 1. Open-type task

Open-type tasks have an indistinct condition, from which it is insufficiently clear how to work, what to use for decision, but the demanded result is clear. Such tasks assume variety of solutions, which are not rectilinear; it is necessary to overcome the arising obstacles. There is a lot of decision versions, but there is no concept of the correct decision: the decision is either applicable to achievement of the demanded result, or not.

The following situations can be the examples of open-type tasks.

Situation 1 (4–5 year-old children). Magic tablecloth. On a magic tablecloth there are two plates. Draw a big apple on a big plate and small apple on a small plate. Paint them. Finish the magic tablecloth by other dishes (Figure 2).

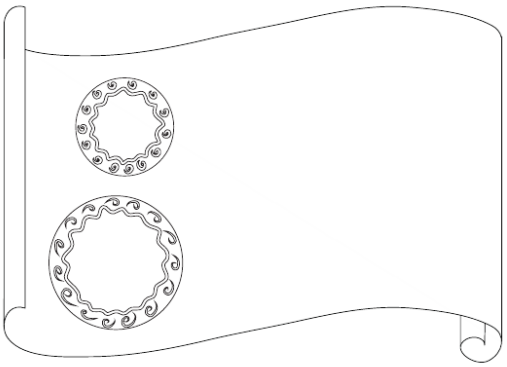

Figure 2. Situation 1 graphic material for preschool children

Situation 2 (6–7 year-old children). Magic mushroom. The magic mushroom is drawn: of your desire, it can become very small or very big. Paint the mushroom.

Finish the drawing by the objects, which make clear that the mushroom possesses this magic property.

Criteria of open-type tasks estimation

To allocate the level of cognitive development, it is possible to use the approved criteria of estimation of open-type educational tasks received on the basis of generalization of creativity indicators (Gilford, 1967; Torrance, 1974). Estimation criteria include measurement on two-point scale of the following indicators:

- efficiency (whether the demanded is reached in a task?);
- optimality (whether the decision is justified?);
- originality (whether the decision is new or known earlier?);
- readiness (whether the decision is detailed or at the level of ideas?)

Thus, estimation criteria define the eight-mark scale, which characterizes the pupil's level of cognitive development.

Estimation of solution of the system, consisting of all-intellectual test and two open-type tasks can become a quantitative index of preschool child's level of cognitive development.

Mathematical-statistical analysis of experimental sample

Let's give the generalized results of mathematical statistics following the results of the 2015 research.

Number of participants in 2015 competition is n = 3781 children.

To define indicators of fluctuation, we break a data set into the groups uniform in the gained total competitive points (table 1).

Let's make the auxiliary table for calculation of the main indicators (table 2).

To assess the number of distribution we l find the following indicators of distribution center.

1) Average weighed (selective average): $x_m = \frac{\sum x_i \cdot f_i}{\sum f_i} = \frac{45352}{3781} = 11.99$.

Thus, the average weighed result of the participant of competition makes 12 points from 22 possible.

2) Mode. The most often found result (mode) of participation is 10 points, as at this result the maximum value of repetitions f = 363.

3) Median. Average result falling on the middle of the ranged (ordered) set (median) are 12 points, as at this value the saved-up frequency of S will be more $\sum f_i/2$ = 1891.

4) Quartiles – the values of a sign in the ranged number of distribution chosen in such a way that 25% of units of population will be less in size Q_1, 25% will be concluded between Q_1 and Q_2, 25% – between Q_2 and Q_3. Other 25% surpass Q_3.

Table 1. Sample distribution on uniformed points

Points	Quantity	Points	Quantity
0	4	12	354
2	4	13	319
3	12	14	246
4	18	15	217
5	54	16	211
6	148	17	151
7	210	18	119
8	332	19	109
9	362	20	100
10	363	21	60
11	362	22	26

Table 2. Calculation of the main indicators

x_i	Quantity, f_i	$x_i \times f_i$	Cumulative frequency, S	$\|x - x_m\| \times f$	$(x - x_m)^2 \times f$	Frequency, f_i/n
0	4	0	4	47.98	575.49	0.00106
2	4	8	8	39.98	399.58	0.00106
3	12	36	20	107.94	970.86	0.00317
4	18	72	38	143.9	1150.48	0.00476
5	54	270	92	377.71	2642	0.0143
6	148	888	240	887.22	5318.61	0.0391
7	210	1470	450	1048.89	5238.9	0.0555
8	332	2656	782	1326.24	5297.96	0.0878
9	362	3258	1144	1084.09	3246.52	0.0957
10	363	3630	1507	724.08	1444.33	0.096
11	362	3982	1869	360.09	358.18	0.0957
12	354	4248	2223	1.87	0.0099	0.0936
13	319	4147	2542	320.69	322.38	0.0844
14	246	3444	2788	493.3	989.21	0.0651
15	217	3255	3005	652.15	1959.89	0.0574
16	211	3376	3216	845.12	3384.93	0.0558
17	151	2567	3367	755.8	3782.99	0.0399
18	119	2142	3486	714.63	4291.56	0.0315
19	109	2071	3595	763.58	5349.07	0.0288
20	100	2000	3695	800.53	6408.47	0.0264
21	60	1260	3755	540.32	4865.71	0.0159
22	26	572	3781	260.14	2602.75	0.00688
Total	**3781**	**45352**		**12296.23**	**60599.89**	**1**

We find x_i, at which cumulated frequency S will be more $\sum f_i/4$ = 946 (x_i = 9). Thus, the first quartile is equal to 9.25% as such number of units of population will be less in size than 9.

Q_2 coincides with a median, Q_2 = 12. We find xi, at which cumulated frequency S will be more $\sum 3f_i/4$ = 2838 (x_i = 15). Thus, the third quartile is equal to 15 (figure 3).

If to calculate average sample error: $D = \frac{\sum(x_i - x_m)^2 \cdot f_i}{\sum f_i} = \frac{60599.89}{3781} = 16.03$; $\sigma = \sqrt{D} = \sqrt{16.027} = 4$, it is possible to notice that each result of participation differs from average value 12 points on average on 4 points. It can speak about uniformity of sample and lack of bigger number of casual results. Uniformity of sample shows moderate value of coefficient of variation, as $v = \frac{\sigma}{x_m} \cdot 100\% = \frac{4}{11.99} \cdot 100\% =$ 33.38%, v > 30%, but v < 70%. Let's prove that results of participation in competition to be described by the normal law of distribution.

5) Asymmetry degree. Let's calculate moment coefficient of asymmetry.

The first group of results	9	The second group of results	12	The third group of results	15	The fourth group of results
Gathered total points						

Figure 3. Sign distribution by quartiles

$As = M_3/\sigma^3$, where M_3 – the central moment of the third order. σ – mean square deviation: $M_3 = 85613.65/3781 = 22.64$; $As = 22.64/64 = 0.35$.

Positive size indicates existence of right-hand asymmetry.

Now we estimate importance of this indicator by means of average quadratic error of asymmetry coefficient: $s_{As} = \sqrt{\frac{6(n-2)}{(n+1)(n+3)}} = \sqrt{\frac{6(22-2)}{(22+1)(22+3)}} = 0.46$.

As, $0.35/0.46 = 0.77 < 3$, asymmetry is insignificant, its existence is explained by influence of various casual circumstances.

Having calculated s_{Ex} – an average quadratic error of coefficient of kurtosis

$$s_{Ex} = \sqrt{\frac{24 \cdot 22(22-2)(22-3)}{(22+1)^2(22+3)(22+5)}} = 0.75.$$

But as $s_{Ex} < 3$, deviation from normal distribution is considered non-essential.

Let's calculate confidential interval for a general average on a formula

$$(x_m - t_{cr} \cdot \frac{\sigma}{\sqrt{n}};\ x_m + t_{cr} \cdot \frac{\sigma}{\sqrt{n}}).$$

In our case $2\Phi(t_{cr}) = \gamma$. $\Phi(t_{cr}) = \gamma/2 = 0.95/2 = 0.475$. According to the table of Laplace function we find $t_{cr}(\gamma) = (0.475) = 1.96$; $t_{cr} \cdot \frac{\sigma}{\sqrt{n}} = 1.96 \cdot \frac{4}{\sqrt{3781}} = 0.13$.

Thus, it is possible to claim with 95% confidence that average value at sample of bigger volume will not go beyond very narrow interval (11.99 – 0.13; 11.99 + 0.13) = (11.86; 12.12).

Summing up the results mathematical statistics, uniformity of sample and validity of the normal law of distribution allow to say that possible results of participation in the competition "Owlet" for preschool children of any age, can be distributed on these groups, each of which contains results of about 25% of participants.

For normalization of the received results, it is possible to use the integrated assessment of relative character – coefficient of cognitive development. By analogy with intellectual tests (such as IQ), the coefficient of cognitive development designates the attitude of "intellectual age" towards real chronological age of the examinee.

Calculation of coefficient of cognitive development is made separately on selection for each age group according to normal distribution of points of participants, so that about 50% of participants, result is lower than 90 test points or higher than 110 test points, got to an interval of 90–110 test points showed approximately on 25% of participants. Thus, 90–110 test points are gathered by participants of the second and third groups of results, participants of 1 group of results gain less than 90 points, participants of 4 groups of results gain more than 110 points (figure 4).

The mathematical-statistical analysis of the offered open-type tasks

Let's consider the results of mathematical statistics on the first and separately on the second creative situation.

For the first creative situation results are the following.

Total points					
The first group of results	9	The second group of results	12	The third group of results	15	The fourth group of results
Coefficient of cognitive development					
Less than 90 points		90–110 points				More than 110 points

Figure 4. Compliance of groups and points of coefficient of cognitive development

Table 3. Sample distribution on uniformed points for Situation 1

Points	Number of participants	Points	Number of participants
0	14	5	377
1	129	6	656
2	308	7	320
3	974	8	292
4	711		

Assessment of average quadratic deviation $s = \sqrt{S^2} = \sqrt{3.52} = 1.88$. Confidential interval for general average (4.47 – 0.0598; 4.47 + 0.0598) = (4.41; 4.53).

For the second creative situation are the following (table 4).

Table 4. Sample distribution on uniformed points for Situation 2

Points	Number of participants	Points	Number of participants
0	40	5	196
1	765	6	201
2	942	7	126
3	851	8	293
4	367		

Assessment of average quadratic deviation $s = \sqrt{S^2} = \sqrt{4.37} = 2.09$. Confidential interval for general average (3.2 – 0.0666; 3.2 + 0.0666) = (3.13; 3.26).

Both selections confirm normal distribution as with s_{Ex} < 3, and confidential intervals for each open-type task show narrow confidential intervals for general average, and the first situation was a little more difficult than the second.

DISCUSSION

Let's notice that the coefficient of cognitive development of preschool child can be an objective assessment in case of performance of the system of tasks considered at calculation of this coefficient. But for estimation of dynamics of cognitive development it is necessary to work the consecutive systems of tasks answering to validity and reliability of research. Also we should note that the used system of tasks within skilled and experimental work is focused on the Russian educational standard of preschool education, regarding essence and content of the concept "cognitive development", in general the system of tasks can be reconsidered taking into account variability of essence and contents of the considered term in the legislation of other countries.

CONCLUSION

It is established that the integration result of performance of open-type tasks system is closely connected with the level of cognitive development during the mastering of educational program of preschool education, requirements to which are described in FSES PE. An assessment of cognitive development level can be the intellectual coefficient of cognitive development reflecting the general abilities of a person, which express informative activity of the subject and his opportunity to assimilation of new knowledge, actions, difficult forms of activity. In this regard we consider that use of intellectual coefficient of cognitive development in the all-Russian system of quality assessment of preschool education and modernization on its basis of a control system of quality of preschool education will promote increase of

efficiency of education and creation of conditions for formation of a new model in this area.

RECOMMENDATIONS

The materials of the article can be useful for tutors, teachers and heads of the preschool educational organizations seeking to increase substantially level of pupils' cognitive development and assess and correct individual educational route of learners at the level of cognitive development.

Taking into account the received results of the research, it is possible to allocate a number of scientific problems and perspective directions demanding further consideration: deepening and extension of some provisions stated in the article, connected with accumulation of psychological-pedagogic potential of tasks used in training; development of scientific-methodological ensuring of wide use of coefficient of cognitive development for assessment the preschool child's level of cognitive development.

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