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Implementation of competency approach in teaching mathematics to primary school children

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Abstract

The article considers implementing the competency approach in teaching mathematics at primary school. The research objective was to check the 4th and 5th grade schoolchildren's skills in solving competency-oriented tasks. The authors used the diagnostic technique consisting in solving mathematical problems that require application of knowledge to real-life situations, understanding of real-life quantities and geometrical figures, and ability to behave relevantly in real-life situations. Typical errors were identified and recommendations on their correction were given. The effective implementation of competency approach requires improving the methods of teaching mathematics at primary school.

Key words: Competency Approach, Mathematical Problems, Teaching.

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Implementando el enfoque basado en las competencias en la enseñanza de matemáticas a los alumnos de la escuela primaria

Resumen

En este artículo se considera la implementación del enfoque basado en las competencias hacia la enseñanza de las matemáticas en la escuela primaria. La investigación se centraba en examinar las habilidades de los alumnos del cuarto y quinto grado en resolver tareas orientadas a las competencias. El método diagnóstico usado por los autores consiste en resolver problemas matemáticos que exigen la aplicación de los conocimientos a situaciones reales, entendimiento de cuantías y figuras geométricas reales y capacidad de comportarse de forma relevante en situaciones reales. Se identificaron errores típicos y propusieron medidas para corregirlos. Para implementar con eficiencia el enfoque basado en las competencias hay que mejorar los métodos de enseñar las matemáticas en la escuela primaria.

Palabras claves: Enfoque De Competencias, Problemas Matemáticos, Enseñanza.

1. INTRODUCTION

Competency approach is one of the key conceptions of the Federal State Educational Standard of general primary education (FSES GPE), implemented in the Russian Federation since 2009. This approach is supposed to bridge the gap between the schoolchildren's knowledge and their skills to apply it for solving real-life problems (Asmolov et al., 2014). It reorients the education system from predominantly transferring knowledge to creating conditions for

mastering key competencies by schoolchildren. Research in the field of competency-based approach has been being done since long ago. In the works by White (1959), Raven (2012), Hutmacher (1997), Zimnyaya (2006), Khutorskoy (2013) and other authors, the concepts of competency and competence are analyzed and compared. Winterton (2006), Holmes (2017) and other authors emphasize that there is no single interpretation of these terms. Our study is based on the definition by Asmolov et al. (2014), which is the most relevant for primary education: competency is "knowledge in action, the ability to establish links between knowledge and the real-life situation" (Asmolov et al., 2014: 13). Competencies are the knowledge and skills that a schoolchild can use further in various areas of one's life.

In the works by M. V. Dubova (2012), Popovich (2014), Tikhonenko (2006) and other authors, it is emphasized that competency approach in teaching junior schoolchildren implies, first and foremost, the practical orientation of the children's activities, the implementation of connection between learning and real-life, and the purposeful formation of schoolchildren's universal learning activities. It is important to offer such tasks, which facilitate the schoolchildren's orientation in the environment, teach to apply knowledge in real-life situations, to make decisions under uncertainty, to flexibly use the developed methods and techniques of acting. Taking into consideration that such material is difficult for junior schoolchildren, it is essential to identify the causes of errors and difficulties, to provide the necessary assistance to children with regard to the problems identified, and to

implement the psychological and pedagogical support of the schoolchildren (Andreeva and Danilova, 2016).

To assess the effectiveness of the competency-based approach implementation, it is appropriate to monitor, as early as at the stage of diagnosing the child's readiness for school, the primary interdisciplinary universal learning activities (Gutsu et al., 2015), and at the stage of teaching to use specially selected tasks of competency-oriented nature (Demeneva, 2015; Ivanov, 2007; Kalinina, 2013; Demidova et al., 2009; Pashkevich, 2016; Selkina and Khudyakova, 2010). In our study, competency-oriented tasks are understood as those requiring application of mathematical knowledge in real-life situations, the ability to orientate in the environment, and presence of real-life ideas about mathematical concepts and ratios. Almost no data is available about the ability of primary school graduates to solve such mathematical problems. This determined the relevance and novelty of our research. The objective of this work is to study the level of 4^{th} and 5^{th} grade schoolchildren's ability to solve competency-oriented mathematical problems, to compare the obtained results, to analyze the main errors and difficulties for children in applying mathematical knowledge and skills in real-life situations, and to develop recommendations for teachers on

implementing the competency approach in the Mathematics lessons at primary school.

2. METHODOLOGY

To identify the 4th and 5th grade schoolchildren's skills of solving competency-oriented tasks, we developed a diagnostic technique which includes 10 tasks united into 4 groups: 8 multiple choice tasks (2 tasks required to explain the answer) and 2 open tasks with a short answer. The 1st group of tasks (tasks 2 and 3) was aimed at identification of schoolchildren's ideas about geometric bodies (sphere, cylinder), abilities to find the specified geometric shapes in the environment and to determine the geometric shape of real objects. The 2nd group of tasks (tasks 5 and 8) was aimed at diagnosing the schoolchildren's ability to use mathematical knowledge in real-life situations. The tasks did not indicate which mathematical knowledge to use. The schoolchildren were to determine that in task 5 it is necessary to calculate the perimeter of a rectangle, as in task 8 – to divide with a remainder, but the answer should be given without the remainder, in accordance with the real-life situation.

The 3rd group of tasks (tasks 1, 4, and 6) was aimed at determining the presence of real-life ideas about quantities (speed, length, weight). The 4th group of tasks (tasks 7, 10, and 9) was aimed at determining the ability of schoolchildren to image the real-life situations and estimate the result in accordance with the given

quantitative data. The competency-oriented tasks were selected in compliance with the types of tasks recommended for assessing the planned results of primary education by FSES GPE (Demidova et al., 2009). Some types of tasks were similar to those included in the national tests in mathematics, conducted at the end of the fourth school year. To assess the confidence of differences between the percentages of the two samples, the φ* – Fischer angular transformation (Fischer criterion) – was used.

The study involved 2 groups of subjects:

The 1st group (525 people) – the 4th grade schoolchildren (aged 9.5–10.5 y. o.). Diagnostic tasks were done by schoolchildren from 24 classes of 20 schools (11 urban secondary schools, 1 lyceum school, 8 rural schools and schools located in regional centers). The 2d group (360 people) – the 5th grade schoolchildren (aged 10.5–11.5 y. o.). Diagnostic tasks were done by schoolchildren from 18 classes in 17 schools (10 urban secondary schools, 7 rural schools and schools located in regional centers). The test confidence was provided by the participation of schoolchildren from urban and rural schools, using manuals by different authors. The diagnostic tasks were done by the children in November–December 2015 and 2016.

3. RESULTS

The results of the diagnostic tasks of different groups accomplished by the 4th and 5th grade schoolchildren are shown in Tables 1–3.

Table 1. Number of schoolchildren giving correct answers to the tasks of the 1st and the 2nd groups, %

	The 1st group of tasks		**The 2nd group of tasks**	
	Task 2	Task 3	Task 5	Task 8
The 4th grade	85.1	68.4	42.5	45.7
The 5th grade	86.1	73.9	51.7	53.9
Value of φ*emp	φ*emp= 0.205	φ*emp = 0.933	φ*emp = 1.421	φ*emp = 1.131
Conclusion about the value of φ*emp	Empirical values of φ* are in the zone of insignificance. $\mathbf{H_1}$ is rejected.			

Table 2. Number of schoolchildren giving correct answers to the tasks of the 3rd group, %

	The 3rd group of tasks			
	Task 1	Task 4	Task 6	
			Correct answer and correct explanation	Correct answer without explanation or with inaccurate, incorrect explanation
The 4th grade	80.8	61.7	62.4	26.7
The 5th grade	82.7	63.9	45.0	32.2
Value of φ^*_{emp}	φ^*_{emp}= 0.354	φ*emp = 0.297	φ*emp = 2.418	φ*emp = 0.778
Conclusion about the value of φ*emp	Empirical values of φ* are in the zone of insignificance. $\mathbf{H_1}$ is rejected.		The received empirical value of φ* is in the area of significance. $\mathbf{H_0}$ is rejected.	The received empirical value of φ* is in the zone of insignificance. $\mathbf{H_1}$ is rejected.

Table 3. Number of schoolchildren giving correct answers to the tasks of the 4th group, %

	The 4th group of tasks			
	Task 7	Task 10	Task 9	
			Correct answer and correct explanation	Correct answer without explanation or with inaccurate, incorrect
The 4th grade	25.5	45.3	22.1	34.3
The 5th grade	20.0	47.2	32.8	30.8
The value of φ*emp	φ*emp =1.011	φ*emp = 1.697	φ*emp = 1.605	φ*emp = 0.453
Conclusion about the value of φ*emp	The received empirical value of φ* is in the zone of insignificance. $\mathbf{H_1}$ is rejected.			

To interpret the results, the levels of the schoolchildren's skills to solve the competency-oriented mathematical tasks were allocated, taking into account the number of correctly solved tasks: advanced level – all 10 tasks were done correctly; above-intermediate level – 8–9 tasks were done correctly (tasks 1–5 and 9, 10 were done correctly, and tasks 6 and 8 were correct, but with inaccurate or incorrect explanation); intermediate level – 7–8 tasks were completed correctly; below-intermediate level – 6 tasks were done correctly; and the low level – less than 6 were done correctly. The results of the distribution of the schoolchildren by the levels are presented in Table 4.

Table 4. Distribution of schoolchildren by the levels of skills for solving the competency-oriented mathematical tasks, %

	Advanced and above-intermediate	**Intermediate**	**Below-intermediate and low**
The 4th grade	13.3	29.3	57.4
The 5th grade	17.2	34.2	48.6
The value of φ*emp	φ*emp = 0.792	φ*emp = 0.764	φ*emp = 1.131
Conclusion about the value of φ*emp	The received empirical value of φ* is in the zone of insignificance. $\mathbf{H_1}$ is rejected.		

4. DISCUSSION

Below we analyze the results of doing each group of tasks by the 4th and 5th grades schoolchildren, and consider the typical errors and difficulties that children had.

The 1st group of tasks

In general, the tasks of the first group were simpler for schoolchildren than the tasks of the 2nd and the 4th groups, and the same difficulty level as the task of the 3rd group. In task 2, the children were to determine which of the given objects (a can, a wheel, a watermelon, and a bucket) had the spherical shape. The correct answer (a watermelon) was given by most of the children – 85.1% of the 4th grade schoolchildren and 86.1% of the 5th grade schoolchildren (φ* emp = 0.205, differences not confident). However, about 12% of children (12.8% of the 4th grade schoolchildren and 10.8% of the 5th grade schoolchildren) selected a wheel option. Such a response

suggests that these schoolchildren do not sufficiently distinguish between flat and three-dimensional figures.

In task 3, children were asked to identify which of the following objects (a can, a wardrobe, a ball, and a cucumber) had the cylindrical shape. The correct answer (a can) was given by about three-quarters of children on average: 68.4% of the 4^{th} grade schoolchildren and 73.9% of the 5^{th} grade schoolchildren (φ^*emp = 0.933, differences not confident). About 16% of the children chose the answer a cucumber and 9% – a wardrobe. Incorrect answers were due to the fact that the children had no idea about a cylinder, although the syllabus on Mathematics for primary school stipulates mastering the ability to recognize and distinguish between geometric figures such as cube, sphere, cylinder, cone, pyramid, and rectangular parallelepiped. For all the junior schoolchildren to master the syllabus on geometrical bodies, the methodological work should be improved in the following directions. The models of three-dimensional figures should be used, so that schoolchildren could hold them, to better comprehend their shape. It is useful to include tasks to find real objects with the given geometric shape in the environment and in pictures. It is also very important to compare plane and solid figures – a sphere and a circle, a cube and a square, a parallelepiped and a rectangle, etc. Searching for their similarities and differences will help children to distinguish more clearly between these figures.

The 2^{d} group of tasks

These tasks were successfully done only by a half of the schoolchildren. In task 5, they were to choose the correct answer for the following problem: Masha wants to edge a rectangular cloth with lace. The sizes of the cloth are 30 cm and 40 cm. How many centimeters of lace will she need? (Options: 70 cm; 140 cm; 1200 cm; 1200 sq. cm). The correct answer (140 cm) was given by about a half of the children: 42.5% of the 4th grade schoolchildren and 51.7% of the 5th grade schoolchildren (φ*emp = 1.421, differences not confident). About a quarter of children were unable to identify that in this task they should calculate the perimeter of a rectangle and not its area, or they mixed the formulas to calculate an area and a perimeter. This is confirmed by the following data: 5.9% of schoolchildren (6.7% of the 4th grade schoolchildren and 4.7% of the 5th grade schoolchildren) chose the answer 1200 sq. cm. and 11.1% of schoolchildren (10.9 % of the 4th grade schoolchildren and 11.4% of the 5th grade schoolchildren) responded that it would take 1200 cm. About one third of children (39% of 4th grade schoolchildren and 32.2% of 5th grade schoolchildren) were unable to analyze the proposed problem and gave the answer 70 cm. Additional analysis of the knowledge and skills of junior schoolchildren showed that, as a rule, children successfully do the tasks explicitly stating that they are to calculate the area or the perimeter of a rectangle or a square. But they have difficulties when they have to apply this knowledge to a specific real-life situation, to understand its mathematical meaning and to determine which formula to use for calculations. In task 8, children were to do the problem: 18

railway tickets in one compartment car were bought for the football team. The ticket numbers were from 1 to 18. How many compartments will the players take, if 4 people can go in each compartment? The task implies an understanding of the specific meaning of division with remainder and applying this knowledge in a real-life situation.

The correct answer is (5 compartments) was given by about half of the schoolchildren: 45.7% of the 4^{th} grade schoolchildren and 53.9% of the 5^{th} grade schoolchildren ($\varphi^{*}emp = 1.131$, differences not confident). About 16% of the children demonstrated the ability to divide with a remainder, but they were unable to cope with the real-life situation: 6.1% of the 5^{th} and 4^{th} grade schoolchildren wrote the answer 18:4 = 4 (remainder 2), and 9.9% of children (13% of the 4^{th} grade schoolchildren and 5.6% of the 5^{th} grade schoolchildren) responded 4 compartments. Some children were reasoning correctly, but did not make the final decision and wrote 4 compartments and 2 places. The mistakes of the schoolchildren giving incorrect answers were different. Some children performed calculations incorrectly; they responded 6 compartments, 3 compartments, etc. Others could not understand the mathematical sense of the task, performing multiplication instead of division; they answered 72 compartments or 72 players. The last answer indicates the difficulties that pupils have with analyzing the text of arithmetical problems. Problems in performing the tasks of the second group are determined by the fact that schoolchildren do not know how to apply even well-formed mathematical knowledge and skills to solve the real-life problems. Therefore, more calculation tasks related to real-life situations should be used in the lessons.

The 3^{d} group of tasks

In general, the tasks of the third group were simpler for schoolchildren than the tasks of the second and fourth groups and the same level of difficulty as the tasks of the first group. In task 1, they had to choose the correct answer: When solving a problem with walking speed, four schoolchildren received different answers. Which of these answers could be true? (Options: 4 km/h; 20 km/h; 30 km/h; 60 km/h). The correct answer (4 km/h) was given by 80.8% of the 4th grade schoolchildren and 82.7% of the 5th grade schoolchildren (φ*emp = 0.354, differences not confident). Other schoolchildren had no idea about the real speeds: 11.2% of the 4th and 5th grade schoolchildren chose the answer of 20 km/h, 3.2% - 30 km/h, 3.7% - 60 km/h, and the rest could not answer.

Task 4 also implied choosing the correct answers: Peter participated in competitions in the long jump with a running start. Which of the following results could Peter show? (Options: 30 cm; 3 m; 8 m; 25 m). This task appeared to be more difficult compared to the previous one, and only about two thirds of the children managed to cope with it. The correct answer (3 m) was given by 61.7% of the 4th grade schoolchildren and 63.9% of the 5th grade schoolchildren (φ*emp = 0.297, differences not confident). About 16% of children (15.6% of the 4th grade schoolchildren and 16.4% of the 5th grade schoolchildren) responded that the length of the jump is 30 cm. formally, this response can be considered real, but it does not take into account that Peter participated in competitions; therefore, this result

does not match the situation. Other schoolchildren chose unreal data: 14.9% of schoolchildren (14.3% of the 4th and 15.8% of the 5th grade schoolchildren) responded 8 m, and 5.8% (7.8% of the 4th grade schoolchildren and 2.8% of the 5th grade schoolchildren) answered 25 m; the rest could not choose. The errors show that the children have no real ideas about values. The reason for this, as a rule, is insufficient experience in performing length measurements. If schoolchildren had participated in measuring the length and width of the classroom and various objects with measuring instruments or meter models, then they would have had the idea that 8 meters are about the length of the classroom, therefore, even the length of the jump of an adult cannot be 8 m or 25 m.

In task 6, the children had to determine whether this may be a true statement: A fifth grade schoolboy Sasha said that he could lift a weight of 4720 g. The answer was to be explained. This task also proved to be rather difficult for children. The correct answer (yes) and the correct explanation (4720 g = 4 kg 720 g; such a weight, i.e., about 5 kg, can be lifted by a fifth grade schoolboy) was given by 62.4% of the 4th grade schoolchildren and 45% of the 5th grade schoolchildren ($\varphi^*_{emp} = 2.418$, the difference is statistically significant, but the best results were shown by the 4th grade schoolchildren and not the 5th grade schoolchildren). The correct answer without explanation, or with an inaccurate or incorrect explanation was given by 26.7% of the 4th grade schoolchildren and 32.2% of the 5th grade schoolchildren ($\varphi^*_{emp} = 0.778$, differences not confident). The children who answered correctly referred to their own experience: I lifted such

weight, this is a baby's weight, etc. Some schoolchildren explained their answer basing on the comparison of the masses of a fifth grade schoolboy and the weight, for example Sasha will be able to lift this weight because his own weight is several times larger, Sasha's mass is larger. But some schoolchildren answering yes, he can give the wrong explanation: Grams are light, Grams are less than a kilogram, etc. It shows the insufficient knowledge about the named numbers. The children compare the units of mass, but do not take into account the real value.

The mistakes of schoolchildren who answered that this statement could not be true were due to two main reasons. A small number of children completed the conversion incorrectly and got the answers of 472 kg, 47 kg 20 g. On this basis, they concluded that the weight was too heavy. The majority of children correctly identified that the weight was about 5 kg, but they wrote that it was very heavy and a fifth grade schoolboy could not lift that weight, that Sasha was too weak for this, and even adults needed to train. Such explanation reflects insufficiency of real ideas about weight among a significant part of the fourth and the fifth grade schoolchildren. To form these ideas, it is important to organize practical work in the classroom and at home, weighing real objects with household weights. This would help the children to orientate in specific data values.

The 4th group of tasks

In task 7, schoolchildren had to choose the correct answer for the problem: The height of a stand for bookshelves is 20 cm. The height of a bookshelf is 30 cm. What is the maximum number of bookshelves that can be put on the stand, if the room height is 3 m? (Options: 6 shelves; 8 shelves; 9 shelves; 10 shelves). The correct answer (9 shelves) was given by 25.5% of the 4th grade schoolchildren and 20% of the 5th grade schoolchildren (φ*emp = 1.011, differences not confident). 24.9% of incorrect responses were due to incomplete use of the problem data; they chose the answer 10 shelves. The primary school textbooks on mathematics offer mainly task on division without a remainder. The children did the task without taking a stand into account. Other schoolchildren (29.6%) chose the answer 6 shelves; they had not thoroughly read and analyzed the text and decided that each of the shelves was placed on a stand. Both of these mistakes were due to the lack of ability to imagine the real-life situation.

In task 10, schoolchildren were to give a correct answer of the question: On the shelf of a store there are packages of potatoes, weighing 2 kg 200 g, 2 kg 700 g, 2 kg 900 g, and 3 kg 100 g. A customer wants to buy two bags of potatoes with a total weight not exceeding 5 kg. Which packages should he get? The correct answer (2 kg 200 g, 2 kg 700 g) was given by 45.3% of the 4th grade schoolchildren and 47.2% of the 5th grade schoolchildren (φ*emp = 1.697, differences not confident). About 6% of children chose answers

2 kg 200 g and 2 kg 900 g (3.1%) or 2 kg 700 g and 2 kg 900 g (3.3%). Such mistakes are due to the children's inability to analyze totally the conditions of the task; they misunderstood the words not more than 5 kg. Schoolchildren also gave some technically correct answers, but without taking into account the requirements of the task; for example, they suggested only one package weighing 2 kg 200 g (6.7% of schoolchildren), 2 kg 700 g (1.8%), or 2 kg 900 g (1.1% of schoolchildren), or two packages 2 kg 200 g each (2.7% of schoolchildren). A common mistake was to select such packages, the weight of which was equal to 5 kg, but without taking into consideration the number of grams: 2 kg 900 g and 3 kg 100 g (5.2% of schoolchildren), or 2 kg 200 g and 3 kg 100 g (3.4% of schoolchildren), or to take the packages, which were not specified in the task at all: 2 kg and 3 kg (2.2% of schoolchildren). Some children found it difficult to choose an option.

Difficulties in solving this task were due to the inability to perform estimations in real-life situations, and the insufficient ability to analyze the problem and consider all existing conditions and data to find the correct solution. In task 9, the children were to choose the correct answer and explain it: Will 1000 rubles be enough to buy four books at 199 rubles for a book and a calendar for 250 rubles? The correct answer (not enough) and the correct explanation was given by 22.1% of the 4^{th} grade schoolchildren and 32.8% of the 5^{th} grade schoolchildren ($\varphi^*_{emp} = 1.605$, differences not confident). The majority of children (15.6%) who gave the correct answer carried out the total calculation: $199 \cdot 4 = 796$; $1000 - 796 = 204$; $204 < 250$, or

199 · 4 + 250 = 1046, 1046 > 1000. And only 11.8% of schoolchildren demonstrated the ability to do estimation based on the rounding of numbers without performing complex calculations. 7.3% of schoolchildren reasoned that: After purchasing four books we will have a little more than 200 rubles. This money is not enough to buy a calendar, and 4.5% gave the following clarification: 199 is about 200, 200 · 4 = 800, 800 + 250 > 1000.

The correct answer (not enough) with no explanation or inaccurate or incorrect explanation was given by 34.3% of the 4th grade schoolchildren and 30.8% of the 5th grade schoolchildren (φ^*_{emp} = 0.453, differences not confident). The rest of the 4th and 5th grade schoolchildren gave the wrong answer due to incorrect calculations or shallow analysis of the problem content. Rather poor results of doing the tasks of the fourth group show the difficulties that children had when performing estimation, the inability to imagine situations and to orientate in them. The similar types of tasks should be offered more often in Mathematics lessons at primary school, the real-life situations and role-playing should be used extensively.

5. CONCLUSION

According to the analysis of the implemented diagnostic tasks, approximately a half of the schoolchildren (57.4% of the 4th grade schoolchildren and 48.6% of the 5th grade schoolchildren, φ^*_{emp} = 1.131, differences not confident) showed low (elementary) level

(34.9%) and below average (below-intermediate) level (18.9%) of the ability to fulfill the competency-oriented tasks. Only seven of the schoolchildren (13.3% of the 4th grade schoolchildren and 17.2% of the 5th grade schoolchildren, φ*emp = 0.792, differences not confident) showed a high (advanced) (2.5%) and above average (above-intermediate) level (12.4%). The rest of the children (29.3% of the 4th grade and 34.2% of the 5th grade schoolchildren, φ*emp = 0.764, differences not confident) performed the diagnostic tasks at an intermediate level. No significant difference was detected in the level of formed skills of solving the competency-oriented tasks between schoolchildren of two groups (the 4th and the 5th grades).

Thus, we confirmed the hypothesis of our research. The data indicate that the level of formed skills of the competency-oriented tasks solving is determined not by the children's age, but by the problems in teaching mathematics at primary school. It is necessary to improve the teaching methods, to strengthen the practical orientation of mathematical tasks, to teach children to orientate in real-life situations that require knowledge application. In Mathematics lessons, it is relevant to widely use project work, role play, practical tasks, searching for the necessary information in various sources, and other methods that implement the competency approach.

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