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32 Lessons for the Development of Cognitive Skills and Metacognitive Skills in 8 Year-old Children

Anatoly Z. Zak

Abstract--- *The following skills were examined: cognitive skills (combinatorial skills, logical skills related to reasoning and comparison, planning skills for problem-solving) and metacognitive skills related to reflection on problem-solving methods. The purpose of the study was to determine the conditions for the development of the above-mentioned skills in 8 year-old children. The assumption was that the "Intellectica" original educational program establishes such conditions. The program includes 32 types of non-standard problems with non-curricular content: 9 narrative-logical problems, 6 comparative problems (comparisons of schematic object representations), 8 spatial problems, 9 route problems (that involve movement of imaginary characters according to specific rules). Each problem type had three structural versions of tasks: find an answer, find the question, find a part of the initial conditions. The control group consisted of 127 children, the experimental group contained 131 children. These children participated in 32 group lessons (weekly, September through May). Initial and final diagnostics of the above-mentioned skills were held in the experimental and control groups. Comparison of results indicates that the children in the experimental group demonstrate significantly higher results than the children in the control group. The study showed that "Intellectica" lessons contribute to the development of the above-mentioned skills in children. In further studies it is planned to determine to what extent the "Intellectica" program promotes the development of the above-mentioned skills of 9 year-old children.*

Keywords--- *8 Year-old Children, Development, Cognitive Skills, Combinatorial Skills, Logical Skills Related to Reasoning and Comparison, Planning Skills for Problem-solving, Metacognitive Skills (Reflection on Problem-solving).*

I. INTRODUCTION

At the present time educational programs of all levels, including elementary school, are growing more complex. Mastering a more sophisticated program requires a higher level of cognitive and metacognitive skill development.

This is why elementary school education must nourish skills related not only to factual, but to conceptual, procedural and metacognitive knowledge (Anderson, L.W. (Ed.), Krathwohl, D.R. (Ed.), Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., Raths, J., & Wittrock, M.C., 2001). Numerous studies were conducted in the beginning of the XXI century on issues, methods and modes of teaching thinking.

1.1. Conditions for Metacognitive Skill Development

Sternberg, R.J., & Grigorenko, E. L. (2007) associate teaching analytical, creative and practical intellect with Sternberg's triarchic theory (1985). The emphasis is placed on metacognitive skills' importance in controlling

Anatoly Z. Zak.

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cognition and detecting its strengths and weaknesses. Teaching thinking and intellectual skills are identified as important sources of intellectual improvement.

Swartz, R.J., Costa, A., Kallick, B., Beyer, B., & Reagan, R. (2007) reveal pedagogical strategies of teaching metacognition to children, which are related to applying different modes of thinking to different tasks.

Perkins, D. (2008) notes that well-developed thinking is related to self-regulation, formulation of heuristics and search strategies.

Shirley Larkin (2009) analyzes conditions for metacognition development in elementary school students and describes metacognitive educational environments.

1.2. Approaches to Stimulating Thinking in Academic Learning

Research conducted by Adey, P. (Ed.) (2008) delineates thinking development programs for children 4-11 years of age.

Dewey, J., & Bento, J. (2009) examine the results of a two-year program that activates thinking in elementary school students, and note an improvement in children's cognitive abilities and social skills and an advance in teachers' professionalism.

De Acedo Lizarraga, M., De Acedo Baquedano, M., Goicoa Mangado, T., & Cardelle-Elawar, M.(2009) investigate intellect stimulation, abstract and deductive argumentation and self-regulation according to the PAEA method.

McGuinness, C., Sheehy, N., Curry, C., Eakin, A., Evans, C., & Forbes, P. (2006) analyze the use of distinctive cognitive tasks for cognitive skill stimulation.

Trickey, S., & Topping, K.J. (2004) conclude that the elementary school “Philosophy for children” program influenced the reasoning and argumentation skill development in elementary school students.

Lucas, B., & Claxton, G. (2010) expound different types of intellect (social, practical, strategic, intuitive, etc.) and practical means for teachers to work on thinking.

Nisbett, R. E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D. F., et al. (2012) review the relationship between intellect and self-regulation, procedural memory and cognitive skills.

Kuhn, D. (2009) emphasizes the importance of understanding knowledge for evaluating educational outcomes.

Shayer, M., & Adhami, M. (2007) assess the efficiency of cognitive skills development while learning mathematics.

Swartz and McGuinness (2014) explore the possibilities of integrating teaching thinking and academic subjects.

Puchta, H. and Williams, M. (2011) study the development of 13 cognitive skill categories, from simple to complex, along with the acquisition of significant practical language skills.

1.3. Methodological Foundations of the Study

The contents of studies considered allows to observe that the majority of researchers explore the prospects of teaching elementary school students complex cognitive skills linked to conceptual, procedural and metacognitive

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knowledge (Anderson, L.W. (Ed.), Krathwohl, D.R. (Ed.), 2001). We find learning simple forms of such skills useful for their acquisition.

Non-curricular exploratory problems are suitable for this purpose. They create favorable conditions for acquiring cognitive skills, since knowledge of the curriculum does not determine the success of exploratory operations (unlike curricular problems). Children with insufficient academic performance act more confidently than while solving academic problems, since this new experience is not tainted with failure. Simple forms of high-level cognitive skills are useful in launching a meaningful dialogue, where each student may propose, justify and rebut arguments.

For the development of simple cognitive skill forms it is expedient to use problems where the difficulty level may be adjusted by changing the number of required operations.

Comparative and reasoning skills are related to conceptual knowledge. The former are developed while comparing schematic images with a specific number of characteristics, the latter are formed while speculating with a certain number of simple arguments.

Planning and combination skills are related to procedural knowledge. The former are developed in the course of transforming one object arrangement into another in a specific number of moves, the latter – while constructing an imaginary character's route on a game field with a specific number of moves according to corresponding rules.

Skills related to metacognitive knowledge are formed on the basis of the above-mentioned problems, when a “metacognitive” task is offered in place of a “cognitive” one, i.e. to verify a solution, rather than to find it.

“Intellectica” program (Zak, A., 2002) includes problems of above-mentioned types for developing cognitive and metacognitive skills.

1.4. Brief Description of the Study

Our research was aimed at developing simple forms of the above-mentioned cognitive skills in children. The goal of the study was to determine the conditions for cognitive and metacognitive skill development in 8-year-old children. Hypothesis: 32 “Intellectica” program lessons serve as a condition of such development. It was determined that children, either independently or with insignificant assistance, were able to solve simple versions of various “Intellectica” program problem types.

The research consisted of three stages. The first stage involved two groups of students (control group – 127, experimental group - 131) solving exploratory problems to determine the degree of cognitive and metacognitive skill development. The second stage involved 32 “Intellectica” program lessons in the experimental group (one weekly lesson). During the third stage children from both groups solving exploratory problems again.

II. MATERIALS AND METHODS

The "Intellectica" program is designed to conduct 32 lessons on the basis of 32 types of non-standard problems with non-curricular content: 9 narrative inference problems (narrative-logical problems), 6 comparisons of schematic object representations (comparative problems), 8 spatial problems, 9 problems that involve movement according to specific rules (route problems). During each lesson the children solve problems of one type.

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2.1. Contents of the «Intellectica» Program

Lesson 1: route problems (type 1). Lesson 2: narrative-logical problems (type 1). Lesson 3: spatial problems (type 1). Lesson 4: route problems (type 2). Lesson 5: comparative problems (type 1). Lesson 6: narrative-logical problems (type 2). Lesson 7: spatial problems (type 2). Lesson 8: route problems (type 3). Lesson 9: narrative-logical problems (type 3). Lesson 10: comparative problems (type 2). Lesson 11: spatial problems (type 3). Lesson 12: route problems (type 4). Lesson 13: narrative-logical problems (type 4). Lesson 14: spatial problems (type 4). Lesson 15: comparative problems (type 3). Lesson 16: route problems (type 5). Lesson 17: narrative-logical problems (type 5). Lesson 18: spatial problems (type 5). Lesson 19: route problems (type 6). Lesson 20: comparative problems (type 4). Lesson 21: narrative-logical problems (type 6). Lesson 22: route problems (type 7). Lesson 23: spatial problems (type 6). Lesson 24: narrative-logical problems (type 7). Lesson 25: comparative problems (type 5). Lesson 26: route problems (type 8). Lesson 27: spatial problems (type 7). Lesson 28: narrative-logical problems (type 8). Lesson 29: route problems (type 9). Lesson 30: comparative problems (type 6). Lesson 31: narrative-logical problems (type 9). Lesson 32: spatial problems (type 8).

2.2. Narrative-logical problems

9 types of narrative-logical problems are as follows:

Type 1, e.g.: “Don, Li and Bob swam across the river. Don swam faster than Li. Li swam faster than Bob. Who swam faster than everyone else?”

Type 2, e.g.: “The words HE, HI, DI are of different colors. Blue and pink words have the same first letter, pink and red – the same second letter. Which word is blue?”

Type 3, e.g.: “Ann and Lo are of different ages. After many years, Ann will be a little older than Lo is now. Who is the younger one of the girls?”

Type 4, e.g.: “Pat, Amy and Sue sent letters: two to Ufa, one to Bor. Pat and Amy, as well as Amy and Sue sent letters to different cities. Where did Pat send her letter?”

Type 5, e.g.: “Three words were written with blue, red and gray paint: SO BE GO. The blue word is to the left of the red, and the gray is to the right of red. What color is the word BE?”

Type 6, e.g.: “Di and Ka had cubes with letters. First, Di composed the word POT. Then he moved the letters and it became TOP. Ka first composed the word ERA, and then moved the letters, in a way identical to Di's. What word did Ka get?”

Type 7, e.g.: “There are three cats – gray, white and black: one is in the room, one in the hall, one in the attic. In the morning either the black cat, or the cat in the attic was fed, in the evening – either the one in the attic, or the white cat was fed. Where was the gray cat?”

Type 8, e.g.: “Ida, Eva and Ana were each given a doll. One doll was in a red dress with long sleeves, the other one– in a red dress with short sleeves, the third one – in a green dress with long sleeves. The dresses of Ida's and Eva's dolls were of the same color, and Eva's and Ana's dolls had dresses with the same sleeves. Who had a doll in a red dress with long sleeves?”

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Type 9, e.g.: “Leo and Dan went to a sports store. Both bought one pair of skis and one pair of skates. One of them liked alpine skis, one – cross-country skis, one roller skates, one – hockey skates. Leo left the store without alpine skis. The boy who chose alpine skis did not buy hockey skates. Who bought roller skates?”

During each lesson the children solve 5 variants of one problems type, e.g. type 1.

Variant 1, e.g.: “Don, Li and Bob swam across the river. Don swam faster than Li. Li swam faster than Bob. Who swam faster than everyone?”

Variant 2, e.g.: “Don, Li and Bob were practicing high jumps. Don jumped higher than Lee. Don jumped higher than Bob”. What question can be answered considering the conditions of this problem: (a) Who jumped higher than Don? (b) What style did Bob jump in? (c) Who jumped lower than Lee?

Variant 3, e.g.: “Don, Li and Bob swam across the river. Don swam faster than Li. […]. Who swam faster than everyone?” What do you need to add to the conditions in order to answer the question of this problem: (a) [Bob swam faster than Don]. (b) [Bob swam as fast as Don]. (c) [Li swam faster than Bob].

Variant 4, e.g.: “Di, Lo and Jim solved the problem: “Don, Li and Bob swam across the river. Don swam faster than Li. Li swam faster than Bob. Who swam slower than everyone?” Answers: (a) Don, (b) Li, (c) Bob. Lo chose answer (a). Di – answer (b). Jim – answer (c). Who made the right choice?

Variant 5, e.g.: “Di, Lo and Jim solved the problem: “Don, Li and Bob were practicing high jumps. Don jumped higher than Lee. Don jumped higher than Bob. Who jumped higher than everyone? Answers: (a) Don, (b) Li, (c) Bob. Lo chose answer (a). Di – answer (b). Jim – answer (c). Who made the wrong choice?

2.3. Comparative Problems

6 types of problems for comparisons of schematic object representations are as follows:

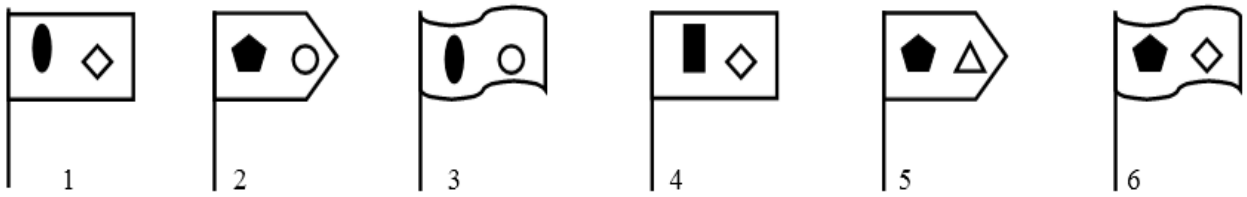

Fig. 1: Flags

Type 1, e.g.: “Consider flags 2, 3, 6. Which flag is similar in shape to flag 6?”

Type 2, e.g.: “Consider flags 1, 3, 5. Which flag has an identical attribute with flag 5?”

Type 3, e.g.: “Consider flags 1, 4, 5. Which flag, 4 or 5, has more identical attributes with flag 1?”

Type 4, e.g.: “Consider flags 2, 3, 6. Which flag, 2 or 3, is similar in shape to flag 6, but has a dark figure on it similar to that of flag 1?”

Type 5, e.g.: “Consider flags 1, 3, 6. Which flag, 1 or 3, has one identical attribute in common with the flag 1 and one identical attribute in common with flag 6?”

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Type 6, e.g.: “Consider flags 1 – 6. Flags 1 and 6 have one identical attribute. Which two flags – 2 and 3 or 1 and 4 – have more identical attributes than flags 1 and 6?”

In each lesson, the children solve 5 variants of one problem type, e.g. type 1.

Variant 1, e.g.: “Consider flags 2, 3, 6. Which flag is shaped similar to flag 6?”

Variant 2, e.g.: “Consider flags 2, 3, 6. What question is suitable for the answer "Flag 2": (a) Which flag has a dark figure like flag 2? (b) Which flag has a light figure like flag 3? (c) Which flag is shaped like flag 6?

Variant 3, e.g.: “Consider flags 3, 6. Which flag has a light figure, like flag 6? Which third flag is needed to answer this question: (a) flag 2, (b) flag 5, (c) flag 4.

Variant 4, e.g.: “Di, Lo and Jim solved the problem: “"Look at flags 1 – 6. Which flag has a light figure, like flag 2?” Answers: (a) flag 1, (b) flag 3, (c) flag 4. Lo chose answer (a). Di – answer (b). Jim – answer (c). Who made the correct choice?

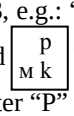
Variant 5, e.g.: “Hi, Mo and So solved the problem: "Look at flags 1 - 6. Which flag has a dark figure, like flag 5?” Answers: (a) flag 2, (b) flag 4, (c) flag 6. Lo chose answer (a). Di – answer (b). Jim – answer (c). Who made the wrong choice?

2.4. Spatial Problems

8 types of spatial problems are as follows:

Type 1, e.g.: “How can the position of letters | S | | R | be changed in two moves so that the following arrangement is obtained | R | S | |?” Rule: one move is the movement of any letter to a free space. Solution: (1) | S | | R | --- | | S | R |, (2) | | S | R | --- | R | S | | or | S | | R | --- | | S | R | --- | R | S | |: in move 1, the letter “S” is moved to the free space, in move 2 – the letter “R” is moved.

Type 2, e.g.: “How can the position of letters | R | R | S | | be changed in two moves so that the following arrangement of digits is obtained | 7 | 4 | | 4 |?” Rule: 1) one move is the movement of any letter to a free space; 2) identical letters should be placed in the same way as identical digits. Solution: | R | R | S | | --- | | R | S | R | --- | S | R | | R |.

Type 3, e.g.: “How can the position of letters:  be changed in two moves so that the following arrangement is obtained  ?” Solution:  ---  ---  in move 1, the letter “K” is moved to the free space, in move 2 – the letter “P” is moved.

Type 4, e.g.: “How can the arrangement of letters:  be changed in two moves so that the following arrangement is obtained  ?” Rule: identical letters should be placed in the same way as identical digits. Solution: ---  --- 

Type 5, e.g.: “How can the following arrangement of letters: P M K be changed in

in two moves so that the following disposition is obtained: K P M?” Rule: one move is **a** simultaneous exchange of two letters. Solution: P M K --- P K M --- K P M: first, the letters M and K switch places, then the letters P and K.

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Type 6, e.g.: “How can the following arrangement of letters: P P M K be changed in two movesso that the following arrangement of digits is reached 6 8 5 5?” Solution: P M M K --- P M K M --- P K M M.

Type 7, e.g.: “How can the following arrangement of letters: P K / M T be changed in two moves so that the following arrangement is obtained: T P / M K” Rule: one move is the simultaneous exchange of two letters. Solution: P K / M T --- K P / M T --- T P / M K

Type 8, e.g.: “How can the following arrangement of letters: P K / P T be changed in two moves so that the following arrangement of digits is obtained 9 4 / 7 4 olution: P K / P T --- K P / P T --- K P / T P.

During each lesson the children solve 5 variants of problems of one type, e.g. type 1.

Variant 1, e.g.: “What two actions need to be performed: (a) | S | | R | --- | | S | R | --- | R | S | | or (b) | S | | R | --- | S | R | | --- | R | S | | so that after two moves the letters | S | | R | are arranged as follows: | R | S | |?”

Variant 2, e.g.: “Which of the following two arrangements will result (a) | S | | R | or (b) | | S | R |, if the arrangement | R | | S | is changed in two moves?

Variant 3, e.g.:“What was the arrangement: (a) | | S | R | or (b) | S | | R |, if after two moves the following arrangement | | R | S | was obtained?

Variant 4, e.g.: “Dan, Mo and Leo solved the problem: “What two actions need to be performed: (a) | S | | R | --- | | S | R | --- | R | S | |, (b) | S | | R | --- | S | R | | --- | R | S | | or (c) | S | | R | --- | R | | S | --- | R | S | | so that after two moves the letters | S | | R | are arranged as follows: | R | S | |?” Dan chose answer (a). Leo – answer (b). Mo – answer (c).Who made the correct choice?

Variant 5, e.g.: “Dan, Jim and Leo solved the problem: “What two actions need to be performed: (a) | T | | H | --- | | T | H | --- | H | T | |, (b) | S | | H | --- | T | H | | --- | H| T | | or (c) | T | | H| --- | R | | H | --- | H| T | |, so that after two moves the letters | T | | H| are arranged as follows: | H| T | |?” Dan chose answer (a). Jim – answer (b). Leo – answer (c). Who made the wrong choice?

2. 5. Route Problems

9 types of problems that involve movement of imaginary characters according to specific rules are as follows.

A	B	C	D	E
F	G	H	I	J
K	L	M	N	O
P	Q	R	S	T
U	V	W	X	Y

Fig. 2: Game Field

Type 1, e.g.: “What two steps did the duck take to get from K to R?”

Rule: 1) “Duck”, an imaginary character, moves through the letters in the cells of the square; 2) the characteristics of its movements are: (a) it steps directly, i.e., into a neighboring cell vertically (e.g.: from cell M to cell H or cell R) or horizontally (e.g.: from M to N or L); (b) it steps obliquely, i.e., diagonally,(e.g.: from M to G or

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I or S or Q); 3) duck can not make two identical steps (two direct steps or two oblique steps) in succession. Solution: K – L – R.

Type 2, e.g.: “What two jumps did the hare take to get from K to E?”

Rule: 1) “Hare”, an imaginary character, moves through the letters in the cells of the square; 2) the characteristics of its movements are: (a) it jumps directly, i.e., through the cell vertically (e.g.: from cell M to cell C or cell W) or horizontally (e.g.: from M to K or O); (b) it jumps obliquely, i.e., diagonally, e.g.: from M to E or A or U or Y; 3) hare cannot make two identical jumps (two direct jumps or two oblique jumps) in succession. Solution: K – M – E.

Type 3, e.g.: “What two moves do the duck and the hare need to make in order to get from G to T?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps only directly, 3) the hare jumps only obliquely – e.g.: duck: L – G, hare: G – S, duck: S – R, hare: R – J. Solution: G – H – T.

Type 4, e.g.: “What two moves do the duck and the hare need to make in order to get from H to S?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps only obliquely, 3) the hare jumps only directly, e.g.: duck: H – N, hare: N – D, duck: D – J, hare: J – T. Solution: H – G – V.

Type 5, e.g.: “What three moves do the duck and the hare need to make in order to get from H to I?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps directly or obliquely, 3) the hare jumps only directly, e.g.: duck: G – L, hare: L – N, duck: N – R, hare: R – T. Solution: H – N – D – E.

Type 6, e.g.: “What three moves do the duck and the hare need to make in order to get from G to J?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps directly or obliquely, 3) the hare jumps only obliquely, e.g.: duck: W – S, hare: S – G, duck: G – B, hare: B – N. Solution: G – M – O – J.

Type 7, e.g.: “What three moves does the duck and the hare need to make in order to get from B to Y?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps only directly, 3) the hare jumps directly or obliquely, e.g.: duck: V – Q, hare: Q – I, duck: I – J, hare: J – S. Solution: B – L – M – Y.

Type 8, e.g.: “What three moves do the duck and the hare need to make in order to get from Q to O?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps only obliquely, 3) the hare jumps directly or obliquely, e.g.: duck: X – R, hare: R – P, duck: P – V, hare: V – N. Solution: Q – I – M – O.

Type 9, e.g.: “What four moves do the duck and the hare need to make in order to get from K to D?”

Rule: 1) the duck and the hare move in turns, 2) the duck steps directly or obliquely, 3) the hare jumps directly or obliquely, e.g.: duck: A – G, hare: G – I, duck: I – D, hare: D – M. Solution: K – L – X – T – J.

During each lesson the children solve 5 variants of one problem type, e.g. type 1.

Variant 1, e.g.: “What two steps did the duck take to get from K to R?”

Variant 2, e.g.: “Which cell did the duck get to in two steps from Q: cell Y or cell N?”

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Variant 3, e.g.: “From which cell did the duck get to Sin two steps: from cell U or J?”

Variant 4, e.g.: “Leo, Dan and Jim solved the problem: “What three steps did the duck take: (a) L – H – I – E, (b) L – M – I – E or (c) L – H – D – E, to get from L to E?” Leo chose answer (a). Dan – answer (b). Jim – answer (c). Who made the correct choice?

Variant 5, e.g.: “Leo, Dan and Jim solved the problem: “What three steps did the duck take: (a) M – L – P – U, (b) M – R – V – U or (c) M – O – V – U, to get from M to U?” Leo chose answer (a). Dan – answer (b). Jim – answer (s). Who made the wrong choice?

The research consisted of three stages. The first stage involved two groups of students (control group – 127, experimental group - 131) solving exploratory problems to determine the degree of cognitive and metacognitive skill development. The second stage involved 32 “Intellectica” program lessons in the experimental group (one weekly lesson). During the third stage children from both groups solving exploratory problems again.

2.6. Enrichment Lessons

Lessons of the "Intellectica" program consist of three parts. During the first part (about 15 minutes) the teacher together with the students analyzes the ways of solving a typical problem. It is necessary for the children to understand what needs to be discovered in problems of this type and how this can be achieved. Children are given the means of analyzing problems (for cognitive skill development) and ways of managing the search for a solution and of controlling their actions (for metacognitive skill development). During the second part (about 30 minutes) children solve 12 to 15 problems independently, applying the knowledge obtained in the first part. During the third part (about 15 minutes), the teacher, along with the students, checks the solved problems and examines incorrect solutions, once again demonstrating the methods of analyzing problems and ways of controlling mental activity.

2.7. Diagnostics of Cognitive and Metacognitive Skills

Before and after the 32 “Intellectica” lessons, group diagnostics was conducted. Letters had to be replaced with single-digit numbers, e.g.: NG + GN = MM is replaced by 24 + 42 = 66. These problems require the use of reasoning skills, comparison, planning and combining.

At first, cognitive skill development was evaluated. The teacher and the students analyzed the problem: T H + P = T T. The rules were expounded: different letters are replaced by different numbers, identical letters – by identical numbers, so that a correct arithmetical expression resulted.

Subsequently, two training problems, – a),b), – and three principal three-digit integer problems were offered:

a) BK + M = BB b) DX - P = DD

1. RMN	2. BHG	3. NVV
+ NMR	- DBH	+ VXX
MKM	UDD	RNN

Training problems' solutions were checked together with the children, the solution of principal ones was not checked. Hereafter, metacognitive skill (reflection on the solution method) development was evaluated. Three problems were posed: the first and the third were structured identically, the second was structured differently.

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1. AE +O = AA; 2. NK + K = NN; 3. XZ + W= XX

After they were solved, children were to select a problem-related statement:

1. Three problems are similar because...
2. Three problems are different because...
3. Problems 1 and 2 are similar, and problem 3 is different from them because...
4. Problems 1 and 3 are similar, and problem 2 is different from them because...
5. Problems 2 and 3 are similar, and problem 1 is different from them because...

The teacher said: “There are five different problem-related statements. Many children solved these problems. Some children said: “all problems are the same”, some said: “all problems are different”, some said: “problems 1 and 2 are similar, problem 3 is different”, others said: “problems 1 and 3 are similar, problem 2 is different”, still others said: “problems 2 and 3 are similar, problem 1 is different”.

Each student has to choose only one statement that he considers the most accurate, and explain this choice.

The problem solutions and the choice of statement during the lesson was not evaluated.

The statement chosen and the explanation were taken into account while evaluating the results.

Some of the children chose statement 1: “... in all problems letters have to be replaced by numbers”.

Some – statement 2: “... in all problems the letters are different”.

Some – statement 3: “... the letters in the third problem are the last in the alphabet, and it's different in the rest...”.

Some – statement 4: “... in the second problem you have to add identical numbers, while they are different in the others...”

Some – statement 5: “... there were vowels in the first problem, and consonants in the others...”.

Statements 1, 2, 3 or 5 are based on similarities and differences in extrinsic problem characteristics. This is a formal understanding that indicates a lack of problem-solving reflection.

Statement 4 is based on problems' structural similarities and differences. It demonstrates a profound understanding of the problems that indicates the presence of problem-solving reflection.

III. Results

3.1. Characteristics of Cognitive and Metacognitive Skill Development

Table

Results in control (C) and experimental (E) groups in September and May.

Skills	Cognitive		Metacognitive	
Period	September	May	September	May
Group C	40 (31.50%)	53 (41.73%)**	31 (24.41%)	41 (32.28%)*
Group E	43 (32.82%)	77 (58.77%)**	33 (25.19%)	60 (45.80%)*

Note: *$p < 0.05$; **$p < 0.01$.

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According to table 1 the level of cognitive skill development increased in both groups as of May – by 10.23% in the control group, and by 25.95% in the experimental group, where the gain was 15.72% greater. The difference in September was minimal – 0.83%, while in May it was statistically significant – 17.04% ($p < 0.01$). The level of metacognitive skill development also increased in both groups – by 7.87% in the control group, and almost threefold, by 20.61%, in the experimental group. The difference in September is minimal – 0.68%, while in May it was statistically significant – 13.52% ($p < 0.01$). In both groups the discrepancy in metacognitive skills in September and May is smaller than in cognitive skills. This confirms a well-known assertion: metacognitive skills develop later than cognitive skills.

IV. DISCUSSION

The conducted research supports the initial hypothesis: “Intellectica” program promotes cognitive and metacognitive skill development in 8-year-old children.

4.1. Experimental Conditions

This result is attributable to “Intellectica” program features: non-curricular content, exploratory nature, differentiation by problem type (narrative-logical, spatial, comparative and route), structural differences, different exploratory activity (find and answer, find a part of the conditions, find a question), different tasks (solve problems, check solutions). Specific lesson characteristics are important: 32 one-hour lessons, held weekly over the course of nine months. Each lesson contains three parts – preliminary discussion, independent problem-solving, concluding discussion. Preliminary discussion teaches analysis and problem-solving methods, and is related to cognitive skill development. Concluding discussion teaches control methods and solution evaluation, and is related to metacognitive skill development.

4.2. Scientific Value of the Study

New knowledge was gained regarding cognitive and metacognitive skill development conditions, expanding and refining developmental psychology perspectives on the prospects of elementary school children's intellectual development.

L.S. Vygotsky's position (1986) “…Therefore the only good kind of instruction is that which marches ahead of development and leads it…” (1986, p.188) is supported. “Intellectica” program lessons contribute to more intensive cognitive and metacognitive skill development (when compared to control group). Such lessons represent a possible vector of the elementary school educational environment's intellectual enrichment.

4.3. Study Limitations

1. Student population. In September an average of 35.38% students solved two problems in both groups, 24.42% solved one problem, and 8.14% - none. With a different group makeup, where the results were, i.e., 40%, 30% and 15%, respectively, lesson efficiency may have been lower.
2. Teachers' characteristics. Teacher experience averaged 15-20 years, while if it was 3-5 years, the development of experimental group children would have been less efficient.
3. No tracking of parental assistance, which, according to teachers, was present to different degrees.

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4.4. Further Research Goals

To conduct an analogous study with 9-year-old children for a fuller and more precise evaluation of the "Intellectica" program's effect on cognitive and metacognitive skill development.

To create an integrated program of teaching Intellectica to elementary school students, where the "Intellectica" program would serve as propedeutics of a critical and creative thinking development program.

V. CONCLUSION

The study demonstrated the efficiency of cognitive and metacognitive skill development in 8-year-old children in a group activity context, where on a regular basis (once a week), over the course of nine months (from September to May), they solved various types of non-curricular exploratory problems contained in the "Intellectica" program.

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