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THE DEVELOPMENT OF LOGICAL THINKING IN JUNIOR STUDENTS THROUGH PROJECT-BASED LEARNING

EL DESARROLLO DEL PENSAMIENTO LÓGICO EN ALUMNOS JÓVENES A TRAVÉS DEL APRENDIZAJE BASADO EN PROYECTOS

O DESENVOLVIMENTO DO PENSAMENTO LÓGICO EM ALUNOS JÚNIOR POR MEIO DA APRENDIZAGEM BASEADA EM PROJETOS

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Abstract: The article takes a new look at the method of developing logical thinking in junior students based on the correlation between the original and the model and making it possible, unlike traditional methods, to develop students' speech thinking, intellectual structures, and logical operations more effectively. With the aid of the epistemological, systemic-activity, and milieu approaches, a strategy for developing students' logical thinking through project-based learning that is premised on the correlation between the original and the model is determined. It ensures the effective development of a) schoolchildren's intellectual activity b) thinking c) logical memory. The study proves the effectiveness of the presented technology, that implies 1) immersing in the project as well as specifying its goals and objectives; 2) organizing and planning students' activities; 3) working out the main stages of the project; 4) carrying out the project and its presentation; 5) evaluating the results. Based on the research data, the following criteria were singled out analysis, synthesis, comparison, classification, generalization, and some other criteria, which allowed determining three levels of the development of the phenomenon in question. Our method provides for a significant improvement of the results of the research and ensures the formation of research, informational, regulatory, and analytical universal learning activities (ULAs). The assessment of the effectiveness and validity of the proposed method are corroborated by calculations for the Fisher's criterion (φ*-criterion). The comparative results of the research before and after the experiment at the high level are 3.564. The obtained empirical values of φ * are in the area of significance. H0 is rejected (the significance axis = 1.64–2.31). Thus, the method in question has a serious impact on the development of logical thinking through project-based learning of junior students.

Keywords: logical thinking, development, correlation between the original and the model, junior student, technology, criteria and levels.

Resumen: El artículo da una nueva mirada al método de desarrollo del pensamiento lógico en alumnos de tercer año basado en la correlación entre el modelo original y el que hace posible, a diferencia de los métodos tradicionales, desarrollar el pensamiento del habla, las estructuras intelectuales y las operaciones lógicas de los alumnos de manera más efectiva. . Con la ayuda de los enfoques epistemológico, de actividad sistémica y de entorno, se determina una estrategia para desarrollar el pensamiento lógico de los alumnos a través del aprendizaje basado en proyectos que se basa en la correlación entre el modelo original y el original. Asegura el desarrollo efectivo de a) la actividad intelectual de los escolares b) el pensamiento c) la memoria lógica. El estudio demuestra la efectividad de la tecnología presentada, lo que implica 1) sumergirse en el proyecto, así como especificar sus metas y objetivos; 2) organizar y planificar las actividades de los alumnos; 3) resolver las etapas principales del proyecto; 4) llevar a cabo el proyecto y su presentación; 5) evaluar los resultados. Con base en los datos de la investigación, se destacaron los siguientes criterios: análisis, síntesis, comparación, clasificación, generalización y algunos otros criterios que permitieron determinar tres niveles del desarrollo del fenómeno en cuestión. Nuestro método proporciona una mejora significativa de los resultados de la investigación y garantiza la formación de actividades de investigación, informativas, regulatorias y analíticas de aprendizaje universal (ULA). La evaluación de la efectividad y validez del método propuesto se corrobora mediante cálculos para el criterio de Fisher (criterio φ *). Los resultados comparativos de la investigación antes y después del experimento a alto nivel son 3.564. Los valores empíricos obtenidos de φ * están en el área de significancia. H0 se rechaza (el eje de significancia = 1.64–2.31). Por lo tanto, el método en cuestión tiene un grave impacto en el desarrollo del pensamiento lógico a través del aprendizaje basado en proyectos de alumnos menores.

Palabras clave: pensamiento lógico, desarrollo, correlación entre el original y el modelo, alumno menor, tecnología, criterios y niveles.

Resumo: O artigo analisa o método de desenvolver o raciocínio lógico em alunos juniores com base na correlação entre o original e o modelo e possibilita, diferentemente dos métodos tradicionais, desenvolver o raciocínio, estruturas intelectuais e operações lógicas dos alunos de maneira mais eficaz. Com o auxílio das abordagens epistemológicas, de atividade sistêmica e do meio, é determinada uma estratégia para o desenvolvimento do pensamento lógico dos alunos por meio da aprendizagem baseada em projetos, baseada na correlação entre o original e o modelo. Garante o desenvolvimento efetivo de a) atividade intelectual das crianças em idade escolar b) pensamento c) memória lógica. O estudo comprova a eficácia da tecnologia apresentada, que implica 1) imersão no projeto, além de especificar suas metas e objetivos; 2) organização e planejamento das atividades dos alunos; 3) elaboração das principais etapas do projeto; 4) realização do projeto e sua apresentação; 5) avaliando os resultados. Com base nos dados da pesquisa, foram destacados os seguintes critérios: análise, síntese, comparação, classificação, generalização e outros critérios que permitiram determinar três níveis de desenvolvimento do fenômeno em questão. Nosso método fornece uma melhoria significativa dos resultados da pesquisa e garante a formação de atividades de aprendizagem universais (ULAs) informativas, regulatórias e analíticas. A avaliação da eficácia e validade do método proposto é corroborada por cálculos para o critério de Fisher (critério φ *). Os resultados comparativos da pesquisa antes e após o experimento em alto nível são 3.564. Os valores empíricos obtidos de φ * estão na área de significância. H0 é rejeitado (o eixo de significância = 1.64-2.31). Assim, o método em questão tem um sério impacto no desenvolvimento do pensamento lógico através da aprendizagem baseada em projetos de alunos juniores.

Palavras-chave: pensamento lógico, desenvolvimento, correlação entre o original e o modelo, aluno júnior, tecnologia, critérios e níveis.

Introduction

Modern conditions implying the modernization of elementary education and requiring innovative change aim to shape a personality capable of thinking creatively, quickly finding its bearings in any situation, gaining independence, and foreseeing the consequences of one's actions. Researchers lay emphasis on developing logical thinking of junior students as it contributes to developing a holistic system of universal learning activities, organizing independent research work, methods of information processing, revealing interconnections and interdependencies of real objects (originals) in the learning process, and forming intellectual culture. This is facilitated by the emergence of textbooks that stimulate students' mental activity.

A special place in this process is occupied by project-based activities, which rest on research, cognitive and creative skills. However, to ensure the effective development of logical thinking in junior schoolchildren it is important for the teacher to organize project-based activities in such a way as to ensure a high level of forming cognitive activity taking into account the students' personal experience in the process of observation (of the original) and creating intellectual structures (models).

Compared with traditional methods, the method of correlation between the model and the original makes it possible to specify the content and structure of the concept of "logical thinking" and to develop a technology for the implementation of projects that allows educators to develop students' speech thinking, intellectual structures, and logical operations more effectively.

Research hypothesis: the development of logical thinking in junior schoolchildren will be effective if we specify the content and structure of this phenomenon and develop a technology for project-based activities resting on the correlation between the model and the original.

The aim of the article consists in working out and implementing the major directions of the development of logical thinking through project-based activities of junior schoolchildren premised on the correlation between the model and the original. This objective is conditioned by the needs of society, junior school, and by the child's personal motivation.

Research Objectives:

- To specify the content and structure of logical thinking in junior students from the methodological and theoretical points of view;

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- To work out a technology for project-based activities aimed at effective development of logical thinking in junior schoolchildren.

Literature Review

The development of logical thinking in the world scientific literature is based on a) speech thinking (Coppola, Mollo, & Pacelli, 2019; Shopina, 2012; Vygotsky, 2016), b) intellectual structures (Davydov, 2005; Zinchenko, 2014; Popova, 2012), c) mental operations in activity (Asmolov, Burmenskaya, & Volodarskaya, 2011; Beloshistaya & Levitas, 2019; Solovyeva, 2015; Zak, 2003; Zankov, 1990).

The ideas of developing logical thinking through schoolchildren's intellectual activities were explored by A.I. Savenkov (2016), A.E. Simanovsky (2018). Reflexive aspects as mechanisms for the creative self-fulfillment of a personality were investigated by V.V. Davydov (2005), L.S. Vygotsky (2016), as well as by the Western scientists J. Bruner (1973), J.P. Guilford (1959), and D. Wechsler (1974).

The provisions for "contemplative education" (Klein, 2018), motivational-emotional relationships and cognitive loads (Hanin & van Njuvenhoven, 2019; Sepp, Howard, Tindall-Ford et al., 2019) are important for the study; and for spatial working memory and its role in the thinking process (Allen, Higgins, & Adams, 2019; Soemer, 2016).

The views of scientists on the importance of research skills formed through TRIZ technologies (Altshuller, 1999; Gorev & Utemov, 2014) are noteworthy that allow developing students' research skills.

A special place in this process is occupied by the organization of the project-based activities of junior schoolchildren (Barashkina, 2018; Morozova, 2017; Lewis, Gerber, Carlson et. al., 2019; Tsvetanova-Churukova, 2012; Shigapova, 2015). The scholars see the significance of project-based activity for the development of logical thinking: a) in the organization of analytical-synthetic activities related to the research skills of singling out problems, their factors and causes; b) in the use of ICT or "smart environments" (Freigang, Schlenker, & Köhler, 2018; Soemer, 2016), multisensory technologies (Vi, Ablart, Gatti et al., 2017), which should be adapted to the age characteristics of junior school children.

Thus, the problem of the development of logical thinking in junior students affects many aspects. However, the analysis of scientific literature shows an insufficient level of theoretical knowledge about the order of using mental operations, and students' inability to

correlate the studied material with their subjective experience in project-based activities, that is, the correlation between the model and the original in students' cognitive activity is not considered.

Some educators have difficulty organizing project-based activities aimed at developing logical thinking in junior students at the stages of setting the research objective, formulating a working hypothesis together with the children, and organizing the stages of the activities in question. All of the above-mentioned factors require solving the first problem: to specify the content and structure of logical thinking in junior students from the methodological and theoretical points of view.

Method

The methodological and theoretical background for the research is based on the epistemological, activity, and milieu approaches. The epistemological approach establishes the dependence of the development of logical thinking on the laws and stages of students' cognitive process, ensuring the transition of thought from the sensuous to the rational (Carvalho & Skipper, 2019; Feldon, Callan, Juth et al., 2019); from the sporadic to the unique and general based on the correlation between the model and the original (Baranov, 2012; Baranov, Burova, & Ovchinnikova, 2015; Barashkina, 2018; Davydov, 2005; Zak, 2003; Morozova & Makarova, 2018). A significant role in this approach belongs to the development of thoughts, behaviour, and emotions (Kalahasthi, Bhuptani, & Kapoor, 2017), consciousness and introspection (Overgaard & Mogensen, 2017; Sepp, Howard, Tindall-Ford et al., 2019). However, the level of complexity of students' cognitive actions should correspond to the stage of their intellectual development (Vygotsky, 2016; Solovyeva, 2015). According to S. P. Baranov, the learning material is a system of models reflecting the knowledge from the experience of humankind. The original represents countless aspects of the object in real conditions and brings the student's knowledge closer to a certain structure of thought. The connection between the model and the original is based on the transitions of thought from the sensuous to the rational and from the abstract to the concrete and leads to a high degree of a student's cognitive activity (Baranov, 2012). Thus, the correlation between the model and the original in logical thinking allows one to expand the process of students' knowledge the outer world.

The systemic-activity approach orientates schoolchildren's research project-based activity towards the gradual stage-by-stage realization of the processes of interiorisation and

exteriorization in thinking, which results in working out mental activity techniques within a certain system (Almazova, Larskih, & Chislova, 2018; Vygotsky, 2016; Davydov, 2005; Zankov, 1990; Leontiev, 2005).

This approach determines the following constituents of the process of developing logical thinking: analyzing structural forms; studying the interconnections and interrelations of the levels of its development; exploring the processes of its development and dynamics based on the correlation between the model and the original. These constituents correlate with the structure of project-based activity implying the following stages: 1) goal-setting, 2) problem statement and hypothesizing, 3) the children's ideas on solving the problem, 4) discovering a new way of solving it, 5) planning group work, 6) creating a project and its presentation, 7) analysis.

The milieu approach characterizes the impact of the environment on various levels of a child's mental development, his or her logical thinking and self-awareness (Bullot, Seeley, & Davies, 2017). It is the very intellectual and ethical atmosphere where a personality develops and which provides natural, cultural, and social conditions influencing junior students. The milieu approach also includes organizational forms of informational impact aided by ICT (information and communication technologies) allow to follow the sequence of actions and logical operations and promptly correcting the students' activities (Lewis, Gerber, Carlson et al. (2019), Freigang, Schlenker, & Köhler, 2018; Soemer, 2016).

Thus, the aforementioned approaches represent a complex interaction of philosophical, social, psychological, and pedagogical views. They allow determining the place of project-based activities in developing logical thinking and creating conditions for a comprehensive study of the problem. What makes up the content of the concepts of "logical thinking of junior schoolchildren" and "project-based activity"? The answer to this question gives the understanding of the problem on the theoretical level.

In psychological and pedagogical literature (Zak, 2003; Tsvetanova-Churukova, 2012), the logical thinking of junior students is treated as a variety of the thinking process which allows a child to use logical concepts and structures characterized by evidentiality, inference, reasoning, and valid conclusion. It is understood as an intellectual structure with clear-cut relations between the analytical-synthetic, abstract-logical (inductive and deductive) kinds of thinking and logical memory. On their basis, the nature of intellectual actions ensuring the effectiveness of the cognitive process is revealed.

The analytical-synthetic thinking of a junior schoolchild ("thinking perception", as defined by D. B. Elkonin (Svenitsky, 2018) is associated with operating images of reality that get transformed into various types of students' cognitive activity. It is an active process characterized by purposefulness, selectivity, and productivity, which is carried out by generalizing the immediate perception of real objects (originals) and creating models. Analytical and synthetic thinking, based on perception, imagination and emotional structures, is carried out by induction, that is, from the simple to the complex, from the sensory to the rational, from the original to the model (Baranov, Burova, & Ovchinnikova, 2015) and presents a synthesis of the results of the student's reasoning and his or her sensory experience and memory (Allen, Higgins, & Adams, 2019).

Abstract-logical thinking enables us to identify the essential features of objects under analysis, to establish their causative-consecutive and functional connections, to realize their essence and role in the educational process in the forms of notion, judgment, and conclusion (Solovyeva, 2015). Verbal-logical thinking is based on linguistic means and speech constructions and correlates thought processes with speech (Shopina, 2012; Coppola, Mollo, & Pacelli, 2019).

Logical memory is based on associations integrating the part with the whole, the type with the variety, causes with effects. It contributes to the assimilation and consolidation of the information received. The connection of logical memory with analytical-synthetic perception and imagination occurs through mental operations (Allen, Higgins, & Adams, 2019). Thus, the logical thinking of younger schoolchildren is a system whose elements are analytical-synthetic, abstract-logical, verbal-logical types of thinking and logical memory, considered in their dynamics and interrelations.

The development of logical thinking in junior schoolchildren is effected through logical operations (Baranov, 2012; Tsvetanova-Churukova, 2012) that help to reveal the studied patterns allowing students to fully realize their intellectual activity defined as a process of a mediated reflection of the world in educational models. On their basis concepts, judgments, and conclusions are formed, creating a system of knowledge and ensuring their relevance.

Comparison, correlation, analysis, synthesis, classification, concretization, conjunction, disjunction, hypothesis, substantiation, and some others refer to logical operations They result in the formation of skills enabling one to consciously apply general methods for solving problems; to correctly carry out the formation of concepts and judgments; to reflect the essential connections and relationships between objects and processes, to competently build

reasoning and evaluate a process or a phenomenon from different points of view. Thanks to logical operations, information is introduced into the student's "semantic field", where it is re-coded and the problem is creatively processed.

The paper focuses on the development of logical thinking through project-based activities of junior students that are defined as a form of students' educational and cognitive activity resulting in a solution to the problem presented in the form of a project (Lat. projectus – throwing forward – an ideal image of the object). It creates conditions for the effective development of students' logical thinking and contributes to the creative formation of the personality, its independence, and active life position.

In the process of organizing students' project-based activities, the formation of the following kinds of ULAs (universal learning activities) takes place: a) research ULAs related to the logical analysis of concepts, judgments and conclusions, coupled with the ability to put forward hypotheses, and offer the best solution; b) informational ULAs, helping students to independently find the necessary information, to generalize and classify it, to determine what information is insufficient to solve the problem; c) regulatory ULAs, aimed at planning activities, an the cooperation and distribution of responsibilities within the group; d) communicative ULAs, implying a student's ability to work in a group; e) presentational ULAs, presenting verbal and non-verbal methods of transmitting information; f) reflexive, answering the questions: "What did I learn?", "What is important to learn?" (Asmolov, Burmenskaya, & Volodarskaya, 2011).

The analysis of psychological and pedagogical literature (Morozova, 2017; Shigapova, 2015) showed that, in accordance with the types of logical thinking and logical operations, research-oriented, creative, and practice-oriented projects are being implemented in junior school.

The solution to the second problem – developing a technology for project-based activities aimed at the formation of logical thinking in junior students – stems from the first one.

The technology of project-based activity in our study includes the following stages, closely associated with the formation of ULAs: Stage 1 – immersion in the project, goal setting, clarification and specification of the goals and objectives of the project; Stage 2 – organizing and planning the students' activity; Stage 3 – developing the main stages of the project; Stage 4 – project implementation and its presentation; Stage 5 – evaluating the results of project-based activities. All the stages of the project are carried out based on the correlation between the

model and the original. Let us demonstrate how the technology is implemented on some types of projects.

The research-oriented project is based on the logic of scientific research. The technology of implementing this type of project implies:

a) The relevance of the project topic, its problem, purpose, object, subject, hypothesis; research tasks;

b) The development and implementation of the main stages of the project, during which the child learns to plan his or her activities, conduct experiments, systematize the obtained information, present the results in the form of messages, tables, and presentations;

C) Discussing the results, making conclusions and recommendations.

Tasks based on collisions, when a child is faced with a lack or excess of information, new conditions for using sensory experience, causing surprise or difficulty, serve as the impetus for the development of logical thinking in research activities.

As an example, let us consider several research-oriented projects carried out within the framework of the presented study: “Lipetsk Khokhloma”, “Yelets Piano Accordion”, “Yelets Lace”, and “Romanovo Clay Toy”.

The goal of the projects: to study the traditions of the folk art of Lipetsk Oblast based on logical operations (analysis, comparison, correlation, generalization).

Project Objectives:

Educational: to generate interest in the work of the craftsmen of Lipetsk Oblast; to introduce the children to the local folk crafts; using the logical methods of comparison, correlation, and analysis, to specify the essential features of various types of folk art; to study the history of the creation of the Yelets piano accordion, Yelets lace, Lipetsk Khokhloma, Romanovo clay toy; to master the techniques of creating objects of local folk (to create a Yelets style lace appliqué to the traditional music performed on the Yelets piano accordion; to create a collection of hand-crafted items).

Developmental: to develop logical thinking, creativity, speech, memory, and imagination.

Didactic: to cultivate a love of folk traditions, to shape the students’ ethical and aesthetic ideas of folk crafts.

Research hypothesis: if there are facts, legends, historical events explaining the traditions of creating Russian folk art, then this art is not new, but is a revival of older (forgotten) arts.

To prove the hypothesis, the children were divided into three groups: sociologists, historians, and artisans. The sociologists made up a questionnaire to discover what children and parents knew about the local folk art. The historians looked up the information about the origin of these crafts, explored the legends and folk tales, looked for artifacts, summed up the results, compared and contrasted the obtained information. The artisans studied the techniques of the crafts, carried out the creative work of making appliqués based on Yelets lace and Lipetsk Khokhloma. Further on, the students put forward ideas on how to preserve old folk crafts, discussed them, selected the best ones, and suggested new ways of implementing the solutions in modern conditions. Comparing elements of old art and new ways of their application, the children concluded that these kinds of art are a revival of the forgotten old art.

The research resulted in giving a talk accompanied by a presentation. Creative projects do not have a detailed structure of group work. They can be carried out in the form of an oral magazine, or a scenario for a school event, and they do not necessarily have a hypothesis. Here is an example of a creative project ("What is New Year?) for junior students carried out by first-year Master's students.

Project goal: to systematize junior students' knowledge about New Year with the help of the logical methods of analysis, comparison, and generalization.

Project Objectives:

Educational: to acquaint the students with the origins of the holiday, to familiarize them with the traditions of its celebration, to systematize the resulting experience.

Developmental: to develop logical thinking, creativity, speech, memory, and imagination.

Didactic: to form aesthetic and ethical ideas about the significance of New Year.

The technology of implementing the project involved the following stages:

Stage 1: Let us talk about the holiday. This stage consists of a number of tasks relating to the development of logical thinking. In particular, it implies a problem talk: when New Year is celebrated, questionnaire, summarizing the differential features of New Year, New Year songs, summarizing the differential features of New Year in songs; a creative task: the write a poem using a certain set of rhymes / draw a New Year gift; finding out curious facts about the holiday ("Did you know that…?"); classifying objects (do the matching and make up a short story).

Stage 2: discussing the problems. It consisted in discussing the New Year menu using logical methods: What would you like to see on your table on New Year's eve? / Tell your

foreign friend how New Year is celebrated in Russia/Compare the celebration of New Year in Russia and abroad.

Stage 3: a DIY gift.

Result: giving a talk accompanied by a presentation.

Each stage of the project is associated with a different correlation between the model and the original.

The practice-oriented project has a clear structure in which the functions of each participant are defined and the results are presented. The development of logical thinking in this project is carried out at all stages of the discussion in the process of correlation of the model and the original. Here are some projects.

Project: “Family Economics”

Project goals: to develop the logical thinking of junior schoolchildren through the use of mental operations (analysis, synthesis, classification, generalization, comparison etc.) as well as the ability to work in groups, and to encourage student’s curiosity.

Project Objectives:

Educational: to teach the students to process a large amount of information and work in a group.

Developmental: to develop the skills of finding information in various sources, of analyzing and systematizing the obtained data, of making conclusions.

Didactic: to educate students about housekeeping and a healthy diet.

The technology of implementing the project involves the following stages:

The stage of immersion in the project is connected with specifying the problem, goals and objectives of the project and the students’ motivation.

The stage of activity planning involves thinking over the concept of the project, consulting with the students’ parents; the teacher’s making up project assignments for each group of students.

Three groups of students worked on the project, each of them did their own assignment. Let us consider their tasks in detail.

Project assignment for Group 1:

Develop a menu for 1 day, calculate the number of calories and make it fit your needs. To do this, use the information presented in the tables “Daily caloric requirements and caloric content of foods”, “The menu and calculation of the amount of food per person”, and “Calories

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burned by exercise". Make conclusions whether or not your diet is healthy. Give a talk on a healthy diet.

Project assignment for Group 2:

Make a family spending plan for a month, taking into account the data presented in the tables: "Sources of income" – wages, state financial support (welfare, pensions, scholarships etc., income from farming); "Budgeting" – regular monthly expenses (food, rent, transportation, entertainments); pocket money for the children and adults; healthcare expenses, buying clothing, furniture, redecoration).

Project assignment for Group 3:

Identify budget items that a family can save on: shopping, conserving water and power, wearing one's clothes carefully. Using the data presented in the fact sheets, calculate the amount of water that we lose when the tap is not properly turned off or the light is not switched off. Prepare drawings showing ways to save resources and the family budget.

In the process of performing these tasks, the following problem solving activities were carried out; while selecting the necessary material, the students were introduced to various sources of information; the project product and an oral presentation were created.

The stage of defending the project. The results of the project were presented at a school event in the presence of the participants' classmates, parents, and schoolmates.

Project: "My native land in numbers".

Project goal: to develop the students' logical thinking with the help of the operations of analysis, synthesis, classification, generalization, and comparison.

Project objectives:

Educational: to shape the students' ideas of their native land using the logical operations of comparison, analysis, and generalization.

Developmental: to compile a collection of mathematical problems based on a classification according to certain properties; to develop the students' logical thinking.

The technology of implementing the project involved the following stages:

1. Immersion into the project. This stage implied stating the problem, setting the goal and determining the objectives of the project; motivating the students.

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2. Activity planning. The students give a home-prepared talk on the rules of creating mathematical problems. The children were offered the following algorithm of creating mathematical problems: a) data collection; b) the selection of the mathematical content and type of problems; 3) establishing a correspondence between the numbers; 4) drawing up the conditions of the problem, its solution and design;
3. Practical work.

Four groups of students worked on the project.

Group 1 worked with various sources of information, selecting interesting facts about the history of their region, its architectural and cultural monuments, nature, and geography.

Group 2 created mathematical problems.

Group 3 selected the illustrative material.

Group 4 produced booklets and collections of mathematical problems.

The project resulted in producing a collection of mathematical problems and the booklet “The history of our native land through mathematical problems”.

In carrying out the project, the following criteria for assessing the collection of mathematical problems and the booklet were worked out:

- Content

1) The information is interesting, useful, and accessible;

2) The collection / booklet corresponds to the project topic and objectives;

3) Grammatical and stylistic mistakes;

- Design

1) The illustrations match or complement the text;

2) The font is readable;

3) The color scheme matches the illustrations and the text;

- Teamwork skills

1) Equal participation in the group work;

2) Coordination and the level of interpersonal relationships organization;

4. Discussing the results.

5. Assessment and analysis.

– Have we achieved the aim of the project?

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– The knowledge of what subjects helped you to carry out the project?

– What kinds of knowledge did you use while carrying out the project?

– Did you enjoy working on the project?

– What new information did you get to know?

Next, the children were asked to assess their teamwork by filling in Table 2 (see Appendix).

Materials and Methods

In order to test the effectiveness of the development of junior students' logical thinking in the process of project-based activities, the following empirical research methods were used: questionnaire, content analysis, and experiment.

Studying the dynamics of the development of logical thinking in junior schoolchildren through project-based activities involved conducting an ascertaining experiment and running a check test during the period from 2018 to 2019. The experimental facility for the research was Secondary School No. 24 named after M.B. Rakovsky. The choice of the school was determined by its active cooperation with the university. The school preserves traditions developed by the prominent Lipetsk scholars K.A. Moskalenko, S.A. Shmakov, and his follower, the former headmaster of the school, M.B. Rakovsky. It has all the necessary conditions for conducting research: well-equipped classrooms, modern ICT, qualified junior schoolteachers. The sample amounted to 98 junior students. The statistical data processing was carried out for 92 recipients. In the course of the research, the following tasks were solved:

1) To determine the criteria and levels of development of logical thinking in junior students;

2) To identify difficulties experienced by children while using logical operations in project-based activity;

In the course of solving the first problem, criteria and indicators for the development of logical thinking through project-based activities were identified. They are presented in Tables 1, 2 (see Appendix).

Based on the use of the methods of A.V. Beloshistoya and V. V. Levitas (2019) and proprietary methodologies (Baranov, 2012; Lazareva, 2018; Tigrova, 2018) three levels of development of logical thinking in junior schoolchildren were identified.

The high level of development is characterized by a significant stock of knowledge and the ability to correlate the model with the original. The child easily divides the whole into parts (analyses it), identifying the essential features that allow distinguishing between parts and the whole. Making generalization, the student the student easily and quickly groups objects according to their essential features. When carrying out a comparison, the student easily finds a large number of similarities and differences between the objects or phenomena, making the right choice of grounds and criteria for comparison. He/she is able to find the basis for classification, to generalize, to single out essential features, and to establish various relationships between concepts. While doing the tasks, the students make minor (if any) mistakes. Their research-oriented, informational, regulatory, communicative, presentational, and analytical ULAs are well-formed.

The medium level of the development of logical thinking implies a large stock of knowledge and concepts, however, the child has some difficulty dividing the whole into parts, and finding common features of the analyzed objects; he or she spends too much time performing the operations of analysis, synthesis, and generalization. He/she does not always refer to his or her personal experience based on real life objects (originals). When making comparisons, the child establishes only a few similarities and differences. In some cases, the child has difficulty grouping objects according to the given criteria. He or she makes some mistakes. His or her research-oriented, informational, regulatory, communicative, presentational, and analytical ULAs are only partially formed.

The low level of the development of logical thinking is associated with significant difficulties in identifying parts in an object, combining elements into a whole and incorrect identification of similarities and differences between objects. When classifying objects, the child has difficulty grouping them according to the given criteria or fails to do it altogether; he or she requires a considerable amount of time. When generalizing, there is a significant investment of time and effort to group only certain items on this or that basis, and often the child does not cope with the task. The student's research-oriented, informational, regulatory, communicative, presentational, and analytical ULAs are poorly formed.

In the course of the ascertaining experiment, while working on the project such a child experienced difficulties with the ability to compare and contrast real and imaginary objects according to identical features; with establishing links between the particular and the general, the model and the original; with grouping objects according to specified characteristics; with

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identifying essential features; with reasoning and formulating the problem and hypothesis of the project.

Results

The results obtained before and after the experiment on the levels of development of logical thinking in junior students are provided in Table 3 (see Appendix). A comparative analysis carried out within the framework of the study shows that there are significant positive dynamics at the high and medium levels demonstrated during the check test. At the high level, the results increased by 1,956 times; at the low level – decreased by 3.9 times.

In order to prove the effectiveness of using various types of project-based activities in the development of logical thinking, φ*emp was used – the criterion for the Fisher angular transformation. φ*emp at the high level after and before the experiment was 3.564. The resulting empirical value φ* is in the area of significance. H_0 is rejected (the significance axis = 1.64–2.31). φ*emp at the low level before and after the experiment was 4.985. The obtained empirical value φ* is in the area of importance. H_0 is rejected (the significance axis = 1.64–2.31). Thus, project-based activity had a significant impact on the development of logical thinking in the junior students participating in the experiment. The developed projects are effective, and the diagnostic results are reliable. The hypothesis has been confirmed, the objectives have been met.

Discussion

We defined the logical thinking of junior schoolchildren as an intellectual structure whose elements are the analytical-synthetic, abstract-logical, verbal-logical types of thinking and logical memory, which were considered in dynamics and interconnection. The development of this phenomenon was carried out through project-based activities associated with logical operations contributing to the investigation of the studied patterns.

The organization of students' project-based activities premised on the correlation between the model and the original is associated with the formation of: a) research, b) informational, c) regulatory, d) communicative, e) presentational, e) analytical universal learning activities that contribute to the development of logical operations. The technology for the implementation of the projects comprised the following stages: 1) immersion in the project;

2) organization of students' activities; 3) working out the main parts of the project; 4) implementation and presentation of the project; 5) evaluation of the results. Based on the criteria for the development of logical thinking and the criteria for the implementation of project-based activities in the group, three levels of their development were determined: high, medium, and low.The impact of various types of project-based activities on the development of logical thinking was proved with the help of φ * emp – the Fisher angular transformation criterion. The obtained empirical value of φ * – at a high level (3.564) is in the area of significance. H_0 is rejected (the significance axis = 1.64–2.31).

Compared with other research (A.Z. Zak (2003), A.E. Simanovsky (2018), T.A. Solovyeva (2015) etc.), this study a) organized project-based activities at various stages of setting the research problem and formulating a working hypothesis with the children; b) developed a technology for the organization of project-based activities in various subjects; c) new knowledge has been gained about the impact of project-based activities on the logical thinking of junior students.

Conclusion

1. The analysis of philosophical and psychological-pedagogical literature made it possible to define the phenomenon of the development of logical thinking in junior schoolchildren in accordance with speech thinking, intellectual structures, the correlation between the model and the original in the transition from the figurative and the concrete to the abstract.

2. The essence of the development of logical thinking in junior students reveals the provisions that determine the logical thinking of junior schoolchildren as a system whose elements are the analytical-synthetic, abstract-logical, verbal-logical types of thinking and logical memory, considered in their dynamics and interrelationships.

3. Methodological and theoretical foundations of this phenomenon are premised on the epistemological, systemic-activity, and milieu approaches, which are a complex combination of philosophical, historical, social, spiritual, moral, psychological, and pedagogical provisions that determine the significance of the development of logical thinking in junior students based on the correlation between the model and the original.

4. The peculiarity of the development of the logical thinking of junior schoolchildren is revealed based on logical operations that make it possible to fully realize students' intellectual

activity, which is understood as the process of a mediated reflection of the world in educational models. The latter form the basis for shaping concepts, judgements, and conclusions making up a system of knowledge and ensuring their relevance.

5. In the process of organizing project-based activities aimed at the development of logical thinking in junior schoolchildren, the formation of research-oriented, informational, regulatory, and analytical ULAs takes place.

6. In accordance with the types of logical thinking and logical operations, research-oriented, creative, and practice-oriented projects are implemented in primary school. The technology for implementing various types of project-based activities related to the development of logical thinking in junior students comprises the following stages: 1) immersion in the project, setting and clarifying the goal and objectives of the project; 2) organizing and planning the students' activity; 3) working out the main stages of the project; 4) project implementation and its presentation; 5) evaluation of the results of the project-based activities.

The results of the pilot study proved the effectiveness of the suggested technologies for the development of logical thinking in junior schoolchildren through project-based activities. The study outlined the prospects for exploring the following areas: designing a structural-dynamic model for the development of logical thinking in junior schoolchildren through research activities, and, in practical terms, the study of the possibilities of using pedagogical conditions and technologies in the educational process of the junior and secondary school.

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Appendix

Table 1. Criteria and indicators of the development of logical thinking in junior schoolchildren

Criteria	Indicators
Analysis	The ease and speed of dividing an object into its component parts for the purpose of studying them; singling out a large number of features

	which distinguish parts and the whole; carrying out a comprehensive analysis; considering individual aspects, properties, component parts; the number and nature of the mistakes made.
Synthesis	The ease and speed of connecting the mentally disassembled objects into a single whole; awareness of the interaction of the parts and the object as a whole; independent completion, filling in the missing components, naming the whole; the number and nature of the mistakes made.
Comparison	The ease of identifying a large number of features or properties of objects; the ability to find common properties and differences of objects; the implementation of the correct choice of grounds and criteria for comparison; the number and quality of errors.
Classification	The ease and speed of grouping or arranging objects on a given basis; the ability to single out the common features of objects and their regular interconnections, to establish similarities and differences; independence in finding the grounds for classification; the number and nature of errors.
Generalization	The ease and speed of combining objects and phenomena according to their differential features; the ability to single out the essential properties of objects and separate them from secondary ones; the ability to make the transition from the idea of the individual contained in the concept, judgment, norm, hypothesis, question etc. to the idea of the general; active reasoning; the number and nature of errors.

Table 2. Evaluating teamwork

Group number ___

Participant's name	Role in teamwork	Completed assignment	Self-assessment of group work participation	Assessment of the participant's work by the group

– active participation, – not active participation, – non-participation

Table 3. Dynamics of the development of logical thinking in junior schoolchildren before and after the experiment

Levels					
High %		Medium %		Low %	
before	after	before	after	before	after
25	48.9	35.1	41.3	39.1	9.8

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