

## DESIGNING THE MATHEMATICS EDUCATIONAL PROCESS IN THE CONTEXT OF EDUCATION METADISCIPLINARITY

### *DESENHANDO O PROCESSO EDUCACIONAL DE MATEMÁTICA NO CONTEXTO DA METADISCIPLINARIDADE DA EDUCAÇÃO*

### *DISEÑAR EL PROCESO EDUCATIVO DE LAS MATEMÁTICAS EN EL CONTEXTO DE LA METADISCIPLINARIDAD DE LA EDUCACIÓN*

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**ABSTRACT:** The article is devoted to one of the current issues – the problem of educational process design. Among the Russian educational space innovations, a special place belongs to the metadisciplinary direction, new for domestic pedagogy. Comprehension of the metadisciplinarity category both in the theoretical aspect and applied from the position of the modern view becomes especially important. To some extent, the complexity of the problem is determined by the ambiguous translation of the prefix “meta.” Recently, there have been many studies devoted to metadisciplinarity. The analysis of scientific works on this problem showed no single point of view on this issue. The axiomatic approach is proposed as one of the options for building an educational strategy in the metadisciplinary field. This study aims to show the possibility of using the latter in designing the mathematics educational process as part of implementing the metadisciplinary direction of the educational standards.

**KEYWORDS:** Educational standards. Interdisciplinarity. Metadisciplinarity. Supra-disciplinarity. Axiomatic approach.

**RESUMO:** *O artigo é dedicado a uma das questões atuais - o problema do desenho de processos educacionais. Entre as inovações do espaço educacional russo, um lugar especial pertence à direção metadisciplinar, nova para a pedagogia doméstica. A compreensão da categoria metadisciplinidade tanto no aspecto teórico quanto aplicada a partir da visão moderna torna-se especialmente importante. Até certo ponto, a complexidade do problema é determinada pela tradução ambígua do prefixo “meta”. Recentemente, muitos estudos têm se dedicado à metadisciplinidade. A análise de trabalhos científicos sobre este problema não mostrou um único ponto de vista sobre o assunto. A abordagem axiomática é proposta como uma das opções para a construção de uma estratégia educacional no campo da*

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*metadisciplinaridade. Este estudo visa mostrar a possibilidade de utilização deste último na concepção do processo educacional em matemática como parte da implementação da direção metadisciplinar dos padrões educacionais.*

**PALAVRAS-CHAVE:** *Padrões educacionais. Interdisciplinaridade. Metadisciplinaridade. Supra-disciplinaridade. Abordagem axiomática.*

**RESUMEN:** *El artículo está dedicado a uno de los temas actuales: el problema del diseño de procesos educativos. Entre las innovaciones del espacio educativo ruso, un lugar especial pertenece a la dirección metadisciplinaria, nueva para la pedagogía doméstica. La comprensión de la categoría de la metadisciplinariedad tanto en el aspecto teórico como aplicado desde la posición de la visión moderna se vuelve especialmente importante. Hasta cierto punto, la complejidad del problema está determinada por la traducción ambigua del prefijo “meta”. Recientemente, se han realizado muchos estudios dedicados a la metadisciplinariedad. El análisis de trabajos científicos sobre este problema no mostró un punto de vista único sobre este tema. El enfoque axiomático se propone como una de las opciones para construir una estrategia educativa en el campo metadisciplinario. Este estudio tiene como objetivo mostrar la posibilidad de utilizar este último en el diseño del proceso educativo matemático como parte de la implementación de la dirección metadisciplinaria de los estándares educativos.*

**PALABRAS CLAVE:** *Estándares educativos. Interdisciplinariedad. Metadisciplinariedad. Supradisciplinariedad. Enfoque axiomático.*

## Introduction

Currently, with a high degree of objectivity, it can be argued that humanity has entered a new period of its development. There are many prerequisites for this: geopolitical changes, the ambitious claims of particular states to leadership, the globalization of almost all spheres of life, and the creation of the digital space. Furthermore, all of them are seen as super-tasks. Under such conditions, the states need highly qualified specialists, proactive, mobile, creative young people, ready to search for new ideas to implement plans for modernization of production, development, and implementation of innovative projects, a breakthrough in all spheres of life. The problems faced by Russian society force us to reconsider the educational policy and develop a new strategic line, which is now becoming an integral part of national security. In this context, great hopes are placed on the school. Consequences of the Russian educational space transformation were the second-generation standards. A new category of “metadisciplinarity” appeared for domestic pedagogical science in these normative documents. The ambiguity of this concept interpretation raises many theoretical and practical questions. At the same time, this has a certain positive point, as it gave impetus to developing scientific

thought but at the same time exposed many problems of applied nature, first of all, to achieve the goals outlined in the standards.

Due to the current circumstances, the contradiction between the needs of society's socio-cultural and economic life in the modernization of education and insufficient development of methodological aspects of the implementation of meta-disciplinary direction of the new standards has now become more acute. The search for ways to resolve this antagonism determined the purpose of this study.

## **Materials and Methods**

The following methods and approaches were used to achieve the goal of the study:

Theoretical methods:

- Analysis of the scientific literature on this issue, resulting in the elucidation of the multidimensionality of the content of the “metadisciplinarity” concept;
- Generalization and systematization of scientific ideas of domestic and foreign scientists, which made it possible to formulate the axiomatics of metadisciplinary environment design;
- Modeling – a new conceptual model was built, which served as the basis for the design of the educational process in the secondary school within the metadisciplinary direction;

Empirical methods:

- Observation of participants in the educational process, conversations with children and teachers; questioning the latter helped to determine the effectiveness of the proposed technology;

Approaches:

- Synergetic approach clarified the content of the category “metadisciplinarity” as an integrative concept;
- Technological approach contributed to the development of procedures to activate the synergy of any scientific field with other academic disciplines.

The authors conducted the present study for three years. The participants in the experiment were 11- and 12-year-olds studying in the fifth grades of secondary educational institutions in the town of Yelets, Lipetsk region of the Russian Federation, without a pre-

selection. The total number of subjects was 70. Mathematics and geography were considered the scientific fields that form the study's foundation.

## Literature Review

The prefix “meta” carries a historical connotation. Involuntarily, the study of this question brings to mind Aristotle's metaphysics. However, the philosopher himself did not call his writings by that name. Andronicus of Rhodes did. Collecting Aristotle's writings, he tried to systematize them in a certain way. As a result, he found materials that could not be classified as philosophy, logic, or physics. Andronicus of Rhodes arranged these works after physics, so Aristotle's metaphysics appeared. From ancient Greek, “meta” is translated as “beyond.”

In the modern interpretation, it means “behind,” “after,” or “over,” which is not typical for the Russian language and has given rise to various interpretations in the definition of the category “metadisciplinarity.” A similar situation arose in the early 90s of the last century when the concept of “technology” entered the pedagogical lexicon. Due to the ambiguous translation from the English language, such terms as “pedagogical technology,” “educational technology,” “learning technology,” “technology in education” appeared in science. On the one hand, as noted above, the situation gives impetus for scientific discussion. However, on the other hand, today, there are no clear benchmarks for implementing the goals stated in the standards in the metadisciplinary direction.

It should be noted that recently there have been many studies on the metadisciplinary direction of the second-generation educational standards (DEGTYAREVA, 2017; MUSINA; SHESTAKOV, 2017; SMIRNOVA, 2018; SUSHENTSEVA; MERLINA, 2016). Nevertheless, two main directions can be distinguished in Russian psychological and pedagogical science. Scientific school, represented by Asmolov (2009), and others, studies the implementation of metadisciplinary direction in the educational process as a comprehensive approach to forming interdisciplinary results. The basis is that interdisciplinary, metadisciplinary components of learning should be considered during the study of individual disciplines. For example, Borovskikh and Rozov (2010) study the content aspect of the problem, contrasting the “metadisciplinarity” concept with the subjectness. They point out: “Activity principles oblige us, when forming an educational program, developing teaching methods, and organizing learning activities, to focus primarily not on the discipline, but on the supra-disciplinary content – on those generalized activity functions which must be developed” (BOROVITSKIKH; ROZOV, 2010, p. 52). Thus, Borovskikh and Rozov (2010) consider

metadisciplinarity as supra-disciplinarity. The topic “Polynomials” (algebra, grade 7) is offered as an example. Algebraic operations over monomials and polynomials are studied. The scientists point out that problems begin when one must find the value of a monomial (or polynomial) by substituting numbers instead of variables. According to Borovskikh and Rozov (2010, p. 56), this manifests “upra-disciplinarity”.

The second research area includes Yu.V. Gromyko, V.V. Kraevskiy, A.V. Khutorskoy. Scientists believe that metadisciplinary results are achieved in studying special courses - meta-disciplines built around a certain thinking organization (sign, task, problem, and others). Khutorskoy (2017) pays much attention to metadisciplinary content, which bears a pre-disciplinary, general disciplinary instrumental function. According to the scientist, the result of the metadisciplinary component of educational standards is the personal achievements (competencies) of school students, which represent an educational product.

The analysis of different viewpoints (ASMOLOV, 2009; DEGTYAREVA, 2017; SMIRNOVA, 2018; SUSHENTSEVA; MERLINA, 2016; KHUTIRSKOY, 2017) allows us to state that some scientists combine metadisciplinarity with interdisciplinarity; others identify metadisciplinarity and supra-disciplinarity. We believe that to address the challenges facing Russian education today successfully, we need to find out the meaning of the categories under consideration. Analyzing a large amount of pedagogical material accumulated by domestic pedagogical science, it can be argued that interdisciplinarity illustrates the applied nature of learning (RYMANOVA, 2018). The study of modern research suggests that metadisciplinarity is also characterized by cognitive culture. The latter is determined by the level of cognitive beginning in the structure of personality, and the category of “supra-disciplinarity” has worldview potential. Thus, from the above characteristics, we can conclude that metadisciplinarity is broader than the concept of “interdisciplinarity.”

Foreign researchers also study meta-disciplinarity from different perspectives, and the range of thematic research is quite broad. Researchers from universities in Canada analyze the relationships between the components of the learning process aimed at achieving metadisciplinary results. They consider the triad: learning objectives → ways and methods of learning → outcomes assessment (KULASEGARAM; RANGACHARI, 2018). It is noted that a special role in this process is played by the issues of assessment of meta-activities (MARZANO, 2016). Using self-assessment, expert assessment, and Open Badges to solve the above problem is of great interest (KAPSALIS *et al.*, 2019). The work also describes their effectiveness, examines the possibility of modeling and analogy.

A particular focus of American research has been on formative assessment is seen as one of the major public strategies for improving learning (MARZANO, 2016; O'KEEFE; LEWIS, 2019). Unlike final assessment - the result of learning for the year or at the end of the class, formative assessment is used throughout the lesson. It has been suggested that this approach helps teachers to adjust their requirements, recommendations, and instructions to students according to their needs. It is pointed out that this kind of assessment can be seen as an assessment of learning (VOINEA, 2018). The main emphasis is placed on the role of feedback; as a result, there is a formation of learning skills. It is possible to distinguish the main components of this process and the relationships between them: learning goals → improvement of learning → self-efficacy development → self-assessment.

Some publications (VAN DER VLEUTEN; SLUIJSMANS; BRINKE, 2017; VOINEA, 2018) investigate the principles of assessment that should underlie the practical choice when developing a specific assessment procedure and the possibilities of using formative assessment technology at science lessons in primary school. The work that deals with educating teachers on recognizing students' ideas (FURTAK *et al.*, 2016) is of interest. Besides, it is proposed to ask questions to determine the level of students' thinking, develop formative assessment tasks, and provide feedback that promotes the development of children's thinking activity.

Summarizing the above, it is obvious that the diversity of approaches to studying this problem is the driving force of research at present. However, despite the sufficient number of works on this topic, the authors of this article believe that today there is a serious need to clarify the basic concept and the need to develop conceptual provisions to effectively organize work in the school in the context of metadisciplinary direction.

## Results and Discussion

If the vector of goal-setting changes, then, naturally, there should be some tactical changes in the design of student and teacher activity, which means that the teacher faces the problem of determining clearer and more concrete benchmarks for its organization.

We see one of the ways to solve the issues raised in designing the educational process using a conceptual approach based on the genesis of the concept “metadisciplinary.” This view allows us to formulate an ideology for implementing new standards in the metadisciplinary field, which is based on a system of axioms. V.M. Monakhov was the first who proposed to use the axiomatic approach in building pedagogical models (MONAKHOV, 2016).

In our case, the following axiomatics developed by the authors is proposed (RYMANOVA, 2019).

Axiom 1 is the axiom of the integrity of the educational process model. Designing and implementing a system of meta-disciplines in the educational process makes it possible to build a holistic didactic system.

Axiom 2 is the axiom of cyclicity of the educational process model. The aggregate of several meta-disciplines, united by common ideological content, represents a single cycle with obligatory characteristics of goal-setting and diagnostics.

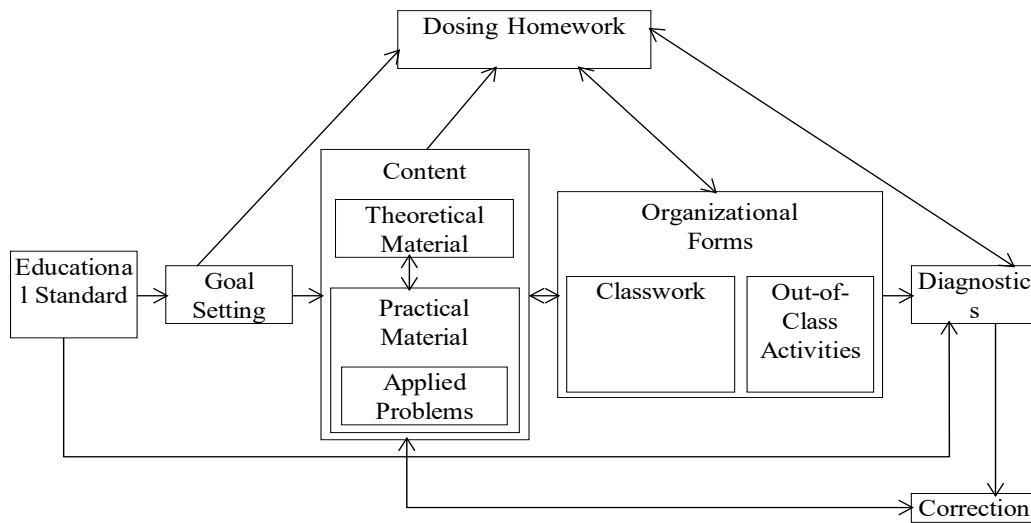
Axiom 3 is the axiom of educational process model optimization. The design of the future educational process should be optimally embedded in the pedagogical model and should fully correspond to the goals outlined in the main educational program.

Axiom 4 is the axiom of normalizing the working field. Designing a conceptual field makes it possible to normalize the working field, which helps build the educational process's logical structure.

Axiom 5 is the axiom of mutually unambiguous correspondence of the working field components. The filling and dosing of content must correspond to the organizational component and vice versa. Mutually unambiguous correspondence between them allows for the development of appropriate methodological tools.

Axiom 6 is the axiom of designing a developmental field. The developmental field allows for optimizing the zones of the nearest development and active development of a school student according to the individual educational trajectory.

The first three axioms define the educational model of the metadisciplinary environment. It is visually represented in Figure 1.

**Figure 1** – The author's educational model of the metadisciplinary environment

Source: Prepared by the authors

The standard sets the benchmarks for designing the educational space and reflects goal-setting and diagnostics. The goals determine the content. The latter force choosing appropriate organizational forms, but the opposite is also possible when the organizational component affects the content aspect. Thus, the content and organization of the educational process are in a didactic interrelationship. Note that the teacher's arsenal has a large set of tools that are not often used in the educational process, such as integrated lessons, practical and laboratory works, debates, and others. Diagnosis determines the correctional work. Correction and content are in a didactic interrelationship. Goal-setting, content, organizational forms and diagnostics determine the dosage of homework, which, in turn, affects the organization of the educational process and control.

The fourth and fifth axioms allow us to build a subject-methodological model of the metadisciplinary environment, a part of which is a working field. Each working field has a conceptual subfield. For example, let us consider the construction of a conceptual subfield of the Real Math meta-discipline for grade 5. First, we analyze the content component of individual science domains, such as mathematics and geography. Let us consider the module “Coordinates” (RYMANOVA, 2018). The result of the work done is presented in Table 1.



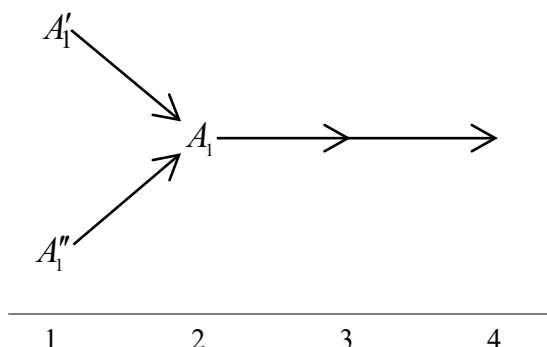
**Table 1** – Analysis of the “Coordinates” module (designed by the authors)

Program modules	Content Component	Results of mastering the content component
Module. Coordinates	Mathematics	
	Introduction to analytic geometry. The coordinate line. The coordinate plane. Point coordinates.	Know how to find coordinates of a point on a straight line, on a plane, construct points using coordinates
	Geography	
	Map, parallels and meridians. Geographic coordinates. Geographic maps in human life	Compare location plans and maps. Determine the geographic coordinates of objects on the map and globe
	Metadisciplinary content	
	Coordinates as a way to describe the position of an object	Solve cognitive problems from different areas of scientific knowledge

Source: Prepared by the authors

Note that such an analysis is performed for each section stated in the course program. After the scope of the content component is clarified, proceed to the construction of the working field (RYMANOVA, 2019). Let us assume that the first lesson considers two auxiliary concepts  $A'_1$  and  $A''$  from two educational areas, and the second lesson is generalized – we get the main concept  $A_1$ . Figure 2 illustrates a lesson-by-lesson drawing of the expected meta-discipline.

**Figure 2** – Model of the working field (author's representation)



Source: Prepared by the authors

It is necessary to take into account that teaching material on the topic “Coordinates” in the courses “Mathematics” and “Geography” in different textbooks is not considered at the same time. Therefore, three variants are possible.

Variant I. When mathematics on this topic is already studied, but geography's one is not, then the working field will look like this:

**Figure 3** – The first variant of the working field (author's representation)

Lessons	1	2	3	4	5	Material under study
Material under study	(G)	(G)	(M)	(MM)	(MM)	
	$A'_1$ $A''_1$ $A_1$					Conceptual field

Source: Prepared by the authors

Hereinafter the following notations are used: G – geography material, M – math material, MM – metadisciplinary material,  $A'_1$  – geographical concept,  $A''_1$  – mathematical concept,  $A_1$  – metadisciplinary concept.

As shown in Figure 3, the first two lessons cover geographic coordinates, the third lesson is Cartesian coordinates re-teaching, and the fourth lesson is a review of the metadisciplinary content of the concept.

Variant II. Students are already familiar with geographic coordinates but have not been introduced to rectangular coordinates in a math class. In this case, the work area will look like this:

**Figure 4** – The second variant of the working field (author's representation)

<b>Lessons</b>	1	2	3	4	5	<b>Material under study</b>
<b>Material under study</b>	(M)	(M)	(G)	(MM)	(MM)	
						<b>Conceptual field</b>

Source: Prepared by the authors

In this case, the first two lessons deal with Cartesian coordinates, the third - with a repetition of geographical material already studied; the fourth is an integrated lesson to clarify the metadisciplinary content of the concept “coordinates.”

Variant III. This variant corresponds to the case when the material on the topic “Coordinates” has been studied in mathematics and geography courses. Then the working field can be represented as follows:

**Figure 5** – The third variant of the working field (author's representation)

<b>Lessons</b>	1	2	3	4	5	<b>Material under study</b>
<b>Material under study</b>	(MM)	(MM)	(MM)	( )	( )	
	$A_1''$ $A_1'$ $A_1$					<b>Conceptual field</b>

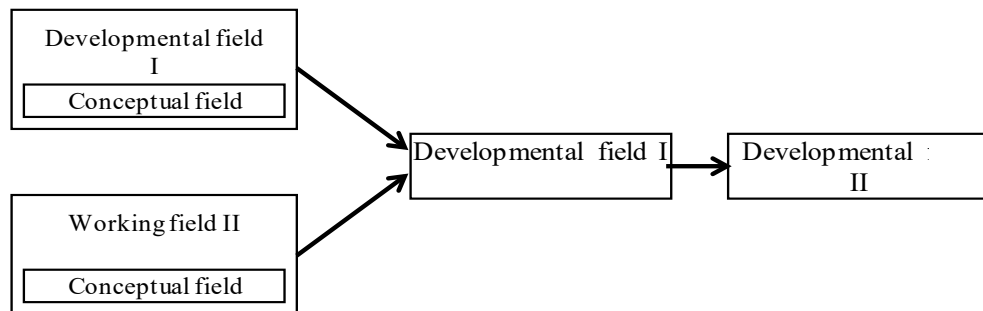
Source: Prepared by the authors

In this case, the teacher immediately proceeds to consider the metadisciplinary content of the concept “coordinates.” Note that this situation is extremely rare.

If necessary, it is possible to optimize the logical structure of the educational process project. The working field programs a system of specific micro goals, each representing the total result of didactic and dialectic tasks.

Axiom 6 makes it possible to reveal the developmental potential of the metadisciplinary environment (Figure 6).

**Figure 6** – Developmental model of the metadisciplinary environment designed by the authors



Source: Prepared by the authors

Note that the trajectory from the working field to the developmental field of level I defines the “zone of the nearest development” (L.S. VYGOTSKY). The trajectory from the developmental field of level I to the developmental field of level II – “zone of active development” (L.S. VYGOTSKY) of the school student. The working field includes the content and organizational components of the disciplinary component and methodological tools.

During experimental work, school students were offered 10 test tasks of metadisciplinary content. The results of the controlled assessment are presented in Table 2.

**Table 2** – Experimental results

At the start of the experiment		At the end of the experiment	
Successfully completed the tasks	15 people	23 people	+11.43%
Made computational errors	16 people	20 people	+5.73%
Misunderstanding the meaning of some items	18 people	16 people	-2.86%
Complete lack of understanding of the question	21 people	11 people	-14.23%

Source: Prepared by the authors

The diagnostics testifies that the methodological component of the proposed educational technology demonstrates a positive effect in the implementation of the goals of metadisciplinary direction.

The real embodiment of the proposed conceptual approach is expressed in a scientifically substantiated building system of meta-disciplines of grades 5-11, with courses of grades 5-9 are interdisciplinary and practice-oriented, and from grade 10 courses that perform supra-disciplinary function are added (RYMANOVA, 2018).

## **Discussion**

The conducted research allows us to state the following:

1. World science has accumulated a certain theoretical and practice-oriented potential in the implementation area of the metadisciplinary component of the learning process. However, the changes currently taking place in the educational space required to make certain adjustments in the details of the category “metadisciplinarity.” The conducted theoretical study made it possible to find out the characteristic features of this concept. The system of axioms was developed, which became the conceptual basis for building a model of a metadisciplinary environment.

2. Within the experimental work based on the proposed axiomatics, the educational and developmental models of the process under study are designed, and relationships between their main components are established. The latter helps to determine the possible deviations from the presented constructions.

3. The theoretical research results were the educational technology's conceptual basis for designing the educational process within the metadisciplinary direction. The methodological tools are based on the axioms presented by the authors. Technological procedures for designing the subject-methodological environment are carried out by embedding the working field, including the conceptual subfield. As a result, forming a metadisciplinary environment is a dialectically controlled process.

4. The diagnostics results allow us to speak about the effectiveness of the developed technology as evidenced by raising performance and quality of knowledge in mathematics and geography in the school students of the experimental group. The teacher's activity moves to a qualitatively new innovative level (RYMANOVA, 2019; RYMANOVA, 2017).

## **Conclusion**

Based on the synergistic approach, the authors clarified the details of the category “metadisciplinarity.” A conceptual model for the formation of a metadisciplinary environment in the school's educational process was designed. The presented design is theoretically justified, making it possible to test it methodologically. The proposed system of axioms is the result of the generalization of psychological, pedagogical, and methodological material accumulated by Russian science. The axiomatic approach makes it possible to build a scientifically grounded project of the future educational process, making it possible to implement the goals of the standard in the metadisciplinary direction.

The working field includes a conceptual field and represents the subject-methodical model of the training topic (module). The working field helps to design a system of special micro goals, each of which is the result of the integration of didactic tasks characterizing the “zone of the nearest development” (L.S. VYGOTSKY) of the school student; as a result, the micro goals acquire a dialectical character. The developing field makes it possible to build an individual child's development trajectory. The proposed axiomatics helps develop technological procedures of the meta-disciplinary environment design, which are the basis of pedagogical technology.

The results of the experimental work and empirical methods allowed us to determine the effectiveness of the approach developed by the authors to solve the problem under study. Observations of the younger adolescents (11-12 years old) showed that they made fewer mistakes when solving mathematical problems by the end of the school year, and such changes were +18%. Progress in geography increased in 22% of school students.

Thus, we can state that the developed axiomatic approach to forming a metadisciplinary environment is a powerful engine for the development of an individual. The abovementioned theoretical and applied aspects formed the basis for the methodological concept of the educational process design. In the future, it is possible to improve further the technological procedures for embedding development programs in the educational process and the development of methodological tools to improve the effectiveness of the developed educational technology.

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