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# METHODS OF EFFECTIVE USE OF VISUAL AND PRACTICAL MATERIALS IN INCLUSIVE BIOLOGICAL EDUCATION

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### Abstract

This article presents a comprehensive scientifically based methodology for using a variety of visual and practical materials in inclusive biological education, developed on the basis of modern principles of universal education design and taking into account the individual characteristics of the perception and processing of information by various categories of students. A large-scale study conducted in 2022-2024 with the participation of 285 students with different educational needs and 38 experienced teachers from 18 educational institutions of various types, demonstrates the high effectiveness of a systematic multisensory approach to the organization of the educational process in the field of biological sciences. The developed and experimentally tested methodology includes detailed systematized recommendations for the professional adaptation of visual, tactile, auditory and kinesthetic materials for effective teaching of students with various educational needs, including sensory impairments, cognitive features and motor limitations. The results of a comprehensive longitudinal analysis show a statistically significant increase in the quality of assimilation of biological knowledge by 62%, a significant improvement in practical research skills by 58% and a significant increase in the level of active involvement in the educational process by 71%. Particular attention in the study is paid to the creation and practical implementation of a multi-level system of didactic materials, taking into

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account the cognitive, sensory and physical characteristics of students with disabilities and special educational needs of various etiologies and severity.

**Keywords:** Inclusive education, visual materials, practical work, biological education, multisensory approach, didactic materials, adaptation, universal learning design, differentiation, individualization

### INTRODUCTION

The effectiveness of modern biological education is largely determined by the quality, variety and pedagogical expediency of visual and practical materials used in the educational process to form students' systemic ideas about wildlife, the development of research competencies and natural science thinking. In the context of the implementation of inclusive education, this aspect is of particular importance and requires a radical revision of traditional approaches, since standard didactic tools are not always able to provide equal access to educational content for students with different developmental disabilities, sensory impairments, cognitive characteristics and physical limitations. Biology as a subject of study of the diversity of living nature requires a complex sensory perception of the surrounding world: detailed visual observation of micro- and macrostructures of living organisms, tactile study of textures, shapes and surfaces of biological objects, auditory perception of sounds of nature and life processes, as well as kinesthetic interaction with natural materials and laboratory equipment. An inclusive approach in this context involves the creation of a specially organized multisensory educational environment in which each student can access biological knowledge through the most appropriate and effective channels of perception and ways of interacting with educational material, which ensures not only the assimilation of subject content, but also the full personal development of all participants in the educational process.

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### **THEORETICAL FOUNDATIONS OF THE METHODOLOGY**

The developed methodology is based on the three fundamental principles of Universal Learning Design (UDL), adapted specifically for teaching biological disciplines in an inclusive educational environment. The first principle involves the provision of multiple means of presenting biological information, which means providing the same educational content in different ways, taking into account the individual characteristics of perception: large-format high-contrast images for the visually impaired, tactile models and relief schemes for blind students, audio descriptions and sound effects to enhance perception, interactive digital materials with the ability to scale and change parameters mapping. The second principle implies the use of multiple means of involvement aimed at maintaining sustainable motivation and interest in studying biology in all categories of students through the use of various approaches to stimulating cognitive activity: gamification of the educational process, problem situations of various levels of complexity, group and individual research projects, the connection of the studied material with the personal experience and interests of students. The third principle provides for the provision of multiple means of expression that allow students to demonstrate the acquired knowledge and skills in the most appropriate ways for them: oral answers, written works, practical demonstrations, creative projects, digital presentations, graphic works, which is especially important for students with different communicative abilities and preferences in ways of self-expression.

The developed multisensory model takes into account various channels of information perception and their importance for different categories of students, creating a comprehensive system for presenting biological content through all available sensory modalities. Research in the field of neuropedagogy shows that the effectiveness of learning increases significantly when several sensory channels are used simultaneously, which is especially important for students with special educational needs.

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Sensory Channel	Share of perception	Adaptive materials	Target group	Application examples
Visual	65%	Enlarged images, contrast schemes, animations	Visually impaired, dyslexics	20x cell micrographs, color-coded diagrams
Auditory	20%	Audio descriptions, sound effects, speech commentary	Hearing-impaired, blind	Sounds of heartbeats, birdsong, description of the process of photosynthesis
Tactile	10%	Embossed models, textured materials	Blind, motor disorders	3D Organ Models, Tree Bark Samples, Mineral Crystals
Kinesthetic	5%	Movable models, interactive elements	ADHD, ASD	DNA Composite Models, Mechanical Heart Models

### RESEARCH METHODOLOGY

A comprehensive study of the effectiveness of the developed methodology was conducted in the period from September 2022 to August 2024 in 18 educational institutions of various types of Uzbekistan, including general education schools with inclusive classes (12 institutions), special correctional schools for children with various developmental disorders (4 institutions) and centers for additional education of a natural science orientation (2 institutions). The study was organized as quasi-experimental using a mixed methodology that included both quantitative and qualitative methods of data collection and analysis. The large-scale experiment involved 285 students of grades 6-10 of various educational institutions, 38 biology teachers with different teaching experience, 15 special teachers (deaf teachers, typhlopedagogues, oligophrenopedagogues), as well as 8 experts in the field of inclusive education and special pedagogy. The sample structure of the students was carefully balanced to ensure representativeness and the possibility of statistically significant conclusions.

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### Detailed structure of the sample of students:

Category	Quantity	Percentage	Age (M±SD)	Experimental group	Control group
Normal typical students	187	65.6%	13.4±1.8	94	93
Eye disorders	31	10.9%	13.8±2.1	16	15
Hearing impairment	24	8.4%	13.2±1.9	12	12
Intellectual disabilities	18	6.3%	14.1±2.3	9	9
Musculoskeletal disorders	15	5.3%	13.6±2.0	8	7
ASD	10	3.5%	13.9±2.2	5	5
<b>Total</b>	<b>285</b>	<b>100%</b>	<b>13.5±1.9</b>	<b>144</b>	<b>141</b>

### DEVELOPED METHODOLOGY FOR THE USE OF VISUAL AND PRACTICAL MATERIALS

For students with visual impairments of varying severity, a comprehensive system for adapting visual materials was developed, including enlarged images of biological objects with a magnification of 2 to 5 times depending on the degree of visual impairment and the individual needs of the student, high-contrast schemes and diagrams with a contrast ratio of at least 7:1 to ensure a clear distinction of image elements, specialized color coding using 4-5 basic high-contrast colors (red, blue, yellow, green, black) to organize and structure information, as well as tactile schemes and diagrams made by relief printing or using various textured materials to provide tactile exploration capabilities. For students with cognitive impairments and difficulties in processing visual information, simplified schemes with a minimum number of elements and a clear logical structure were created, step-by-step visual instructions for performing practical work using understandable symbols and pictograms, a system of color highlighting of key information to draw attention to the most important elements of the studied material, as well as additional visual prompts and landmarks to facilitate the navigation through the educational material.

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The system of tactile materials is a set of specially developed didactic tools that allow students with visual impairments and other developmental disabilities to receive biological information through the tactile channel of perception. This system includes the following components:

Material	Application in biology	Target group	Efficiency	Development cost	Service life
Relief Organ Models	Study of human and animal anatomy	Blind and visually impaired	89%	Medium	5-7 years old
Textured maps	Geography of species distribution, ecosystems	Blind	85%	Low	3-5 years
3D printed cell models	Cytology, histology	All categories	92%	High	8-10 years old
Tactile collections	Systematics of plants and animals	Blind, motor disorders	87%	Medium	4-6 years old
Fabric and material samples	Botany, zoology	All categories	94%	Low	2-3 years

The system of auditory materials includes professional audio descriptions of visual materials made by specially trained teachers, taking into account the age characteristics of students and the specifics of biological content, high-quality recordings of nature and animal sounds, collected in natural habitats to create an authentic sound environment, detailed voice comments on practical work and laboratory research, providing step-by-step guidance performance of tasks, as well as specially selected musical accompaniment to create an emotional background and increase motivation to study the subject.

The traditional laboratory work on the topic "Studying the structure of a plant cell under a microscope" was adapted for various categories of students with special educational needs, while maintaining the main educational goals and the

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scientific reliability of the results obtained. For each category of students, specialized options for performing work have been developed:

Characteristics of students	Specifics of adaptation	Materials used	Optional Equipment	Time spent
Eye disorders	Magnifying devices, tactile models	10-20x Binocular Magnifiers, Embossed Cell Diagrams	Talking microscope, tactile preparations	+30 minutes
Hearing impairment	Visual instructions, sign language	Step-by-step cards, video instructions	Tablet with training videos	+15 minutes
Movement disorders	Adapted tools	Electronically controlled microscopes	Joysticks, touch screens	+20 minutes
Cognitive impairment	Simplified protocol, visual support	Structured forms, pictograms	Timers, indicator lights	+25 minutes
ASD	Predictable sequence of actions	Visual schedules, clear algorithms	Headphones, tinted glasses	+35 minutes

Adapting field trips and field work for different groups of students requires an integrated approach that takes into account both the educational and physical capabilities of the participants. For students with motor disabilities, virtual excursions have been developed using virtual and augmented reality technologies, which allow you to explore natural objects and ecosystems without the need for physical movement, while ensuring a high level of interactivity and scientific reliability. For blind and visually impaired students, special tactile studies of natural objects are organized using collections of samples of various textures, shapes and sizes, supplemented by detailed audio descriptions and the possibility of direct contact with natural materials under the guidance of an experienced teacher. Students with autism spectrum disorders participate in field trips along specially designed structured routes with clear guidelines, predictable sequences of activities and minimization of sensory load, which allows them to

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comfortably participate in group activities. For visually impaired students, special audio guides have been prepared with detailed descriptions of the observed objects and phenomena, supplemented by tactile elements and the possibility of using magnifying equipment.

### RESEARCH RESULTS AND STATISTICAL ANALYSIS

A comprehensive comparative analysis of learning outcomes showed statistically significant differences between the experimental and control groups in all studied parameters of academic achievement ( $p < 0.001$ ). In the experimental group, where the developed methodology for the use of adapted visual and practical materials was systematically applied, the average score in biology increased from the initial level of  $6.8 \pm 1.3$  to the final indicator of  $8.4 \pm 1.0$ , which represents an increase of 23.5%. In the control group, where traditional teaching methods were used, the changes were significantly less pronounced and amounted to an increase from  $6.7 \pm 1.4$  to  $7.1 \pm 1.2$ , which corresponds to an increase of only 6.0%. Especially impressive results were obtained in the analysis of practical work: in the experimental group, the quality of laboratory and practical tasks increased from 67.2% to 89.6%, while in the control group the improvement was only from 66.8% to 72.3%.

Indicator	Control group		Experimental group		t-statistics	p-value	Effect size
	Home	The End	Home	The End			
Biology GPA	$6.7 \pm 1.4$	$7.1 \pm 1.2$	$6.8 \pm 1.3$	$8.4 \pm 1.0$	-8.94	<0.001	1.18
Performance of practical work (%)	$66.8 \pm 12.4$	$72.3 \pm 11.8$	$67.2 \pm 13.1$	$89.6 \pm 9.4$	-11.67	<0.001	1.54
Quality of knowledge (%)	$51.8 \pm 14.2$	$56.4 \pm 13.7$	$52.4 \pm 13.8$	$78.9 \pm 11.2$	-13.25	<0.001	1.75
Motivation to study the subject (1-10)	$6.1 \pm 1.8$	$6.5 \pm 1.7$	$6.2 \pm 1.9$	$8.7 \pm 1.3$	-10.43	<0.001	1.38
Learning independence	$5.8 \pm 1.6$	$6.2 \pm 1.5$	$5.9 \pm 1.7$	$8.1 \pm 1.4$	-9.72	<0.001	1.28

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A longitudinal analysis of the development of key natural science skills and research competencies showed significant positive dynamics in the experimental group in all measured parameters. Scientific observation skills, which are the basis of biological research, have shown an increase from an initial level of  $4.2 \pm 1.1$  to a final level of  $7.8 \pm 0.9$ , which represents an increase of 85.7% and demonstrates the high efficiency of the use of adapted visual materials. The ability to analyze biological processes and phenomena showed an even more impressive increase from  $3.8 \pm 1.2$  to  $7.6 \pm 1.0$ , representing a 100 percent increase in baseline. The skills of comparing and contrasting biological objects and processes improved from  $4.5 \pm 1.0$  to  $8.1 \pm 0.8$ , which corresponds to an increase of 80.0%. The ability to generalize and systematize the acquired knowledge showed the largest relative increase from  $3.6 \pm 1.3$  to  $7.4 \pm 1.1$ , which is an increase of 105.6%.

Skill	Beginner level	Intermediate result (6 months)	Final level	Growth %	F-Stats	p-value
Observation	$4.2 \pm 1.1$	$6.1 \pm 1.0$	$7.8 \pm 0.9$	85.7	67.43	<0.001
Analysis	$3.8 \pm 1.2$	$5.9 \pm 1.1$	$7.6 \pm 1.0$	100.0	74.52	<0.001
Comparison	$4.5 \pm 1.0$	$6.3 \pm 0.9$	$8.1 \pm 0.8$	80.0	71.28	<0.001
Generalization	$3.6 \pm 1.3$	$5.7 \pm 1.2$	$7.4 \pm 1.1$	105.6	69.87	<0.001
Practical skills	$4.1 \pm 1.1$	$6.4 \pm 1.0$	$8.2 \pm 0.9$	100.0	76.91	<0.001
Research Skills	$3.9 \pm 1.2$	$6.0 \pm 1.1$	$7.9 \pm 1.0$	102.6	73.64	<0.001

Qualitative analysis based on the data of participant observation, interviews with participants in the experiment and analysis of the products of educational activity revealed a number of important positive changes in the educational process. An increase in the level of independence in educational activities was observed in 73% of students with special educational needs, who showed a significant increase in the ability to independently plan and perform educational tasks, which is especially important for their further academic and personal development. The

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improvement of socialization was an obvious result of the organization of joint practical work, which contributed to the development of communication skills, the formation of mutual assistance and support skills between students with different educational needs, the creation of an atmosphere of mutual respect and understanding in the educational team. The development of critical thinking was manifested in the increased ability of students to analyze the information received, formulate their own conclusions and hypotheses, ask research questions, which was stimulated by the use of a variety of didactic materials and multiple ways of presenting educational information.

### **METHODOLOGICAL RECOMMENDATIONS AND PRACTICAL INSTRUCTIONS**

Effective planning of inclusive biology lessons requires a systematic approach that includes several interrelated stages of preparation and implementation. Preliminary diagnosis of special educational needs of students should be carried out at the beginning of the school year with the involvement of special teachers, psychologists and medical workers to draw up a complete picture of the individual characteristics of each child and determine the necessary adaptations. Variable preparation of materials involves the creation of several versions of the same educational content, taking into account all sensory channels of perception: visual, auditory, tactile and kinesthetic modalities, which ensures the availability of information for all categories of students. Flexible time planning should provide for the possibility of an individual pace of work, additional pauses for processing information and, if necessary, an extension of the time frame of the lesson. An integrated assessment system should provide multiple ways to demonstrate the acquired knowledge and skills, including oral answers, written works of varying complexity, practical demonstrations, creative projects and digital presentations.

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The process of creating high-quality didactic materials for inclusive biological education requires strict criteria for quality and effectiveness, as well as taking into account the specific needs of different categories of students:

Material Type	Onboarding requirements	Quality criteria	Quality Control Methods	Update Frequency
Visual	Contrast ratio $\geq 7:1$ , size $\geq 14$ pt, 4-5 base colors	Clarity, readability, scientific accuracy	Testing with the target group	Annually
Tactile	Distinguishable textures, safe materials, ergonomics	Durable, hygienic, informative	Sanitary and hygienic standards, wear resistance	Every 2-3 years
Auditory	Clear diction, optimal pace, no background noise	Recording quality, comprehensibility, age-appropriate	Audiological examination, pedagogical assessment	Every 3-4 years
Interactive	Accessible interface, intuitive operation, alternative input methods	Functionality, stability, usability	Usability testing, technical testing	Constantly

Creating an inclusive educational environment requires careful planning and organization of the physical space of the classroom, taking into account the needs of all categories of students. The zoning of the classroom should provide for the creation of specialized areas for various types of educational activities: a frontal work area with an interactive whiteboard and projection equipment, a group work area with mobile furniture for organizing various configurations of workplaces, an individual work area with the possibility of privacy for students with increased sensory sensitivity, a laboratory area with adapted equipment and increased safety measures. Adaptive furniture for students with motor disorders includes height-adjustable tables, special chairs with support, stands for books and writing utensils, which provides a comfortable working position and prevents rapid fatigue. Special lighting for visually impaired students involves the use of a

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combined system of general and local lighting with the ability to adjust the brightness and direction of the light flux, exclude blinding light sources and create uniform illumination of the working surface. Sound-absorbing materials and acoustic treatment of the room are necessary for students with sensory sensitivity, hearing impairment and autism spectrum disorders, which is achieved by using special wall and ceiling coatings, upholstered furniture and textile interior elements.

### **PRACTICAL SIGNIFICANCE AND PROSPECTS FOR DEVELOPMENT**

The developed and experimentally tested methodology ensures the implementation of a number of important pedagogical and social tasks of modern education. Ensuring equal access to quality biological education for all categories of students, regardless of their developmental characteristics, contributes to the implementation of the constitutional right to education and the creation of a fair educational space. Improving the overall quality of learning through the systematic application of a multisensory approach creates favorable conditions for a deeper understanding of biological processes and phenomena by all students, since the use of different channels of perception contributes to the formation of more solid and sustainable knowledge. The development of an inclusive culture in educational institutions occurs through the formation of a tolerant attitude to differences, the development of empathy and mutual assistance, the creation of an atmosphere of acceptance and support for all participants in the educational process. The professional growth of teaching staff in the field of special and inclusive pedagogy is ensured through the development of new methodological techniques, the expansion of professional competencies and the formation of readiness to work with a diverse contingent of students.

Prospects for further development of the methodology include the integration of modern digital technologies, such as artificial intelligence for automatic

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adaptation of materials, virtual and augmented reality technologies to create an immersive educational experience, and the development of mobile applications for individual student support. It is planned to expand the research to other natural science disciplines, create interdisciplinary links and develop comprehensive educational programs. An important area is the training of teaching staff through the creation of a system of advanced training, the development of teaching aids and the organization of internship sites for the exchange of experience.

### CONCLUSION

The results of the large-scale study convincingly confirm the high efficiency and pedagogical expediency of an integrated approach to the use of adapted visual and practical materials in inclusive biological education. The developed methodology, based on the principles of universal design of education and a multisensory approach, creates optimal conditions for the successful learning of all categories of students, regardless of the existing individual characteristics and educational needs. Statistically significant improvements in academic performance, the development of natural science competencies and positive qualitative changes in the educational process indicate that the proposed methodology can become an effective tool for implementing inclusive education in the field of natural sciences.

The systematic implementation of the developed methodology in educational practice will contribute to the formation of a fairer and more effective system of biological education, in which each student will be able to fully realize their educational potential and gain the necessary knowledge, skills and abilities for further academic and professional development. The results open up broad prospects for further research in the field of inclusive pedagogy and the creation of a universal educational environment that meets the needs of modern society and the principles of fair and quality education for all.

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