Experimental Verification of Using Augmented Reality Technology for Teaching Global Reading to Preschoolers with Autism Spectrum Disorders

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Abstract: The article focuses on the use of augmented reality technology for visualizing educational information for children with ASD during teaching global reading and systems of Augmentative and Alternative Communication (AAC). It is noted that while learning, children with ASD display such features as quick fatigue, low concentration, constant distraction and difficulties in building communications. Based on the developed and tested corrective- developmental methods, an algorithm for forming a technology for teaching global reading to children with ASD was defined. The main stages of such training were determined: 1) creation of "safe" interaction for the child; 2) learning to select the inscriptions under the pictures (if the child pronounced the name correctly, he was offered to "revive" the picture with the help of augmented reality technology); 3) selection of words for objects (pictogram images), verbs (the cat begins to move – runs); 4) work with individual handouts: compose sentences and read aloud; 5) use of PECS alternative communication (cards have inscriptions) – children fix visual image of the word; 6) using a mnemonic table in augmented reality for reading. The stages of an empirical study of the effectiveness of teaching global reading to children with ASD using augmented reality technology were defined. An empirical research program was developed, which included problem-search, diagnostic, empirical-synthesizing and interpretive-summary stages. For each stage, the main achieved results were formulated and research methods were substantiated. The main technical possibilities of using augmented reality technology in teaching global reading to children with ASD were characterized. The results of diagnostics of children with ASD before and after the experiment were presented. Empirical data were compared and a conclusion was drawn about the effectiveness of the proposed methodology for teaching global reading to children with ASD.

1 INTRODUCTION

In the context of shaping the European-oriented development of the educational space in Ukraine, against the backdrop of the existing challenges in teaching and nurturing children with mental developmental disorders, the utilization of modern information and communication technologies in pedagogical activities gains significant relevance. In Ukraine, as well as globally, there is a gradual quantitative increase in children with Autism Spectrum Disorder (ASD). According to international research, Ukraine ranks 96th in terms of the prevalence of ASD worldwide (Wisevoter, 2023). Thus, Ukraine is home to 160,444 individuals with ASD, out of which 31,617 are children. The prevalence rate of childhood autism is 463.9 per 100,000.

The increasing trend of ASD prevalence in Ukraine and globally has prompted experts to search for new methodologies and technologies for educating and developing this category of children.

Given the reform of the domestic education system and the inclusion of children with ASD in the mainstream educational framework, the acquisition of communication skills and appropriate socialization become even more pressing issues. It should be emphasized that the diagnostic criteria for Autism Spectrum Disorder include a triad of symptoms that manifest by the age of three (Wetherby et al., 1998):

1) disorders in social interaction;

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2) disorders in verbal/non-verbal communication;

3) repetitive, stereotyped, restricted behavior and activities.

Consequently, the acquisition of communication skills for children with ASD is among the most crucial matters, as they not only encounter difficulties in communication and language but also challenges in understanding and utilizing non-verbal behavior in communicative interactions.

It is worth noting that one of the means to develop communication skills and enhance a child's vocabulary is through reading instruction. However, we understand that the process of reading is complicated for children with ASD due to their limited language function. In our study, we will focus on the utilization of augmented reality technology for visualizing educational information during global reading instruction and for augmentative and alternative communication (AAC) systems. Visualization of educational information relies on visual memory and is well-suited for children with ASD.

2 RELATED WORK

The issue of teaching children with autism spectrum disorders is being studied by many researchers, including Ukrainian ones (Ostrovska et al., 2018; Tarasun, 2022; Khvorova, 2011; Skrypnyk and Lozova, 2020; Shulzhenko, 2009; Romanchuk, 2016; Sinyov, 2007; Shevtsov, 2009).

In particular, Tarasun (2022) and Khvorova (2011) were engaged in the study of issues related to the development, education, and socialization of children with autism. They developed contemporary medical-psychological-pedagogical and neuropsychological approaches to the study of Autism Spectrum Disorders (ASD) and created authorial techniques for diagnosing the development peculiarities of children with autism. They proposed a system for intensifying the development correction of children with ASD, including various approaches, a roadmap for autologic assistance, and methods for correcting the socio-emotional and communicative-language development of children with ASD. Skrypnyk and Lozova (2020) developed a methodology for the formation of the communicative and language sphere of preschool children, known as 'Sensory Integration Ayres' and 'Sensory Diet,' which are methods based on the ideas of the regularities of development and active participation in life activities. Shulzhenko (2009) examines the issues of psycholinguistic aspects of speech peculiarities in children with autistic spectrum disorders

and proposes approaches to studying the genesis of the speech phenomenon within the mental structure of autistic children.

Based on foreign research (Bonora et al., 2019; Light and McNaughton, 2012; Stone, 2004), it is possible to distinguish two categories of deviations of social and communicative development in children with ASD, namely: the ability to divide attention, which is associated with difficulties in coordinating attention between people and objects; and the ability to use symbols, which is associated with the difficulties of conventional symbolic meanings and affects acquisition of speech, the use of gestures and game actions (Stone, 2004).

In addition, the issue of implementation and verification of the effectiveness of modern AAC systems becomes urgent. The international experience of rehabilitation practice shows wide use of AAC tools (reading books and communication boards, glyphs) and their general applicability due to their high practical usefulness (Bonora et al., 2019). However, the use of augmented reality for teaching global reading to children with ASD is a unique development of its kind, the ultimate goal of which is formation of children's oral speech.

The development and utilization of augmented reality for teaching children with ASD, especially global reading, is a unique innovation aimed at enhancing children's oral communication skills. The AR technology relies on the visual memory of children with autistic spectrum disorders, which is well understood by them due to the combination of graphic word representation with a real object. The rationale for employing augmented reality technology in teaching ASD children global reading was substantiated in our previous publication (Tarasun, 2022). The logical continuation of our work will entail highlighting the practical results of the experimental research on the application of AR technology in teaching global reading to children with ASD.

Research objective: to experimentally assess the effectiveness of augmented reality technology in teaching global reading to preschoolers with ASD through the use of augmented reality technology and Alternative and Augmentative Communication (AAC).

The article uses the *methods* of analysis, comparison, systematization, experiment, diagnostics according to the CARS and PEP-R methods, the method of mathematical data processing, data generalization and interpretation.

3 RESULTS AND DISCUSSION

The research has indicated that the issue of teaching reading to children with ASD is fairly widespread and challenging. This is attributed to the fact that children with ASD tend to quickly tire, get distracted, and exhibit a specific need for maintaining consistency in their environment, following established routines, schedules, images, and drawings, among other aspects. Hence, the utilization of visual information or "visual support," characterized by the clear presentation of information, significantly contributes to the better assimilation of educational materials by children with ASD.

The process of teaching global reading to children with Autism Spectrum Disorder follows a certain sequence and stages, taking into consideration the degree of expression of autistic disharmony. In our study, the staged approach consisted of the following components (Kolomoiets and Kassim, 2018):

1) establishing a "safe" interaction environment for the child;

2) teaching the child to match labels with pictures (if the child correctly pronounced the name, we offered to "animate" the picture using augmented reality technology);

3) associating verbs (e.g., the cat begins to move – it runs) with the subject items (pictograms to pictures);

4) working with individual booklets: forming sentences and reading aloud;

5) employing augmentative and alternative communication (AAC) using PECS (picture exchange communication system) cards – children reinforce the visual image of the word;

6) utilizing mnemonic tables in augmented reality for reading.

It's important to note that adhering to such an algorithm in the teaching process will contribute to the development of language skills in children.

The use of augmented reality (AR) tools in working with children presents specific features (Syrovatskyi et al., 2018):

1) formation of a new understanding of educational material based on cognitive and emotional experiences – ensuring emotional and cognitive engagement;

2) the potential to enhance the realism of the studied material through "living" images;

3) introducing new ways of presenting real learning objects.

In the modern educational environment, three main categories of augmented reality educational systems are identified: "visualization of 3D images for visualizing educational material; recognition and labeling of real objects oriented in space; interaction between a computer-generated virtual object (or smartphone) and a person in real-time mode" (Tsyrulnyk, 2019).

Among the key characteristics of augmented reality are the following (Syrovatskyi et al., 2018):

- combining real-world objects with computer-generated data;

- enhancing real-world objects with computer-generated sensory data (sound, video, graphics, position);

- creating a semantic context that merges physical and digital spaces, where objects of association are located in the real world;

- simplified display of virtual objects compared to virtual reality;

- controlled interaction with the learning object for exploring its features.

It's worth noting that the contemporary social and educational environment, both general and specialized, is infused with tools that facilitate the integration and application of augmented reality. Given the comprehensive development of this approach in the modern world, we have decided to test the effectiveness of using AR in working with children with ASD.

Based on the aforementioned stages in teaching children with ASD global reading and incorporating augmented reality elements into this process, we conducted practical research on the outlined issue. Our study was based at the "Kryvyi Rih Special Multi-profile Educational and Rehabilitation Center No. 1" under the Dnipropetrovsk Regional Council.

Our research was divided into four main stages. The first, the problem- search stage, involved defining the goal, developing an empirical research program, justifying the relevance of the proposed technology in special education. We selected methods (experiment, descriptive and comparative methods of analysis, generalization, logical method), as well as augmented reality tools. An experimental methodology and its targeted model were created.

The empirical research program on the effectiveness of augmented reality technology in teaching global reading to children with ASD is presented in table 1.

The second – **diagnostic** – stage was aimed at processing documents (medical reports, conclusions of psychoneurological institutions, psychological and

Table 1: Program of empirical study on the effectiveness of augmented reality technology in teaching global reading to children with ASD.

Experiment program (stages)	The main tasks achieved	Methods of research and work
Problem-search stage	The goal was defined, the expediency of using augmented reality technology in special education was substantiated, methods and tools of work were chosen, an experimental methodology and its target model were created	Experiment, descriptive and comparative methods of analysis, generalization, logical method
Diagnostic stage	The use of a complex of psychodiagnostic methods before the start of experimental work	CARS scale, PEP-R developmental scale profile. Speech examination
Empirical-synthesizing stage	1. Development of visual perception, formation of the ability to analyze, distinguish and generalize, orient oneself in space	Methods and techniques are aimed at forming simultaneous syntheses of a clear internal schematization of experience
	2. Work aimed at understanding words and correlating them with images	Synthesis of individual elements into consecutive series (Tarasun, 2022)
	3. Performance of visual movements, vestibular projections, formation of optical and kinesthetic sensations, development of sensorimotor abilities and successive structures at the cognitive level	Visual systems: Picture Exchange Communication Symbols (PECS), Picture Communication Symbols (PCS), platform Blippar, methods of teaching global reading
	4. Development of expressive, narrative, fluent reading	Pictograms of I. Koroliova, L. Nuriieva
	5. Vocabulary formation: antonyms, paronyms, synonyms	The child selects a card with the appropriate image and correlates it with the word on the card
Interpretive-summary stage	The use of a complex of psychodiagnostic techniques after the experimental work. Statistical processing of empirical data. Description and interpretation of the results before and after the implementation of the experimental teaching method. Formulation of research conclusions and results. Outlining prospects for further research in this context	Method of mathematical data processing. Methods of empirical data interpretation. PEP-R Developmental Scale Profile

pedagogical characteristics, psycho-corrective programs), and application of CARS scales for evaluating children's autism manifestations, the profile of the PEP-R development scale before the start of training.

The parameters of the diagnostic toolkit included the specificity of the scales, reliability, validity, standardization of methods for displaying personal characteristics. The Psychoeducational profile revised (PEP-R) is a set of skills and behaviors that serve as a diagnostic toolkit for determining a child's characteristic ways of learning. The test is designed to assess the development of children with autism and children with developmental disorders, it is designed for preschool age (from 6 months to 7 years). The materials for the test include the study of imitation skills, perception, fine and gross motor skills, visual-motor coordination, cognitive activity, communication and active speech.

Note that 21 children aged 3 to 7 years old took part in the diagnostics. The initial distribution of children according to gender and age characteristics is presented in table 2.

Table 2: Distribution of respondents according to gender and age characteristics.

Gender	Age		
	3-4 years	5-7 years	Total
Male	9	5	14
Female	4	3	7
Total	13	8	21

The PEP-R scale elements are divided into seven areas of development: imitation; perception; fine motor skills; gross motor skills; eye-motor coordination; cognitive activity; communication, active speech. Within our study, we were most interested in the results on the last scale. The results of the initial check are presented in figure 1.

Thus, the initial data according to the PEP-R developmental scale indicate age-inappropriate speech in a significant number of preschool children with ASD – 76.19%. In addition, 23.81% of respondents have no speech at all. The obtained data indicate the need for the development and correction of speech in children with ASD.

The next method we chose was the "Childhood Autism Rating Scale" (CARS), which was used to diagnose a child's non-standard behavior: assessment of the size of the problem (conformance to the norms of behavior – "appropriate", "moderately appropriate", "largely non-compliant". The scale consists of 15 items: "Relationships with people", "Body control", "Imitation", "Emotional reaction", "Using objects", "Adaptation to changes", "Visual reaction", "Aural reaction", "Taste, smell, reaction to touch", "Shyness or nervousness", "Verbal communication", "Non-verbal communication", "Activity level", "Level and degree of intellectual development", "General impression". It allows to diagnose children with autism, distinguish them from children with developmental disorders, but without autism syndrome.

Using the specified diagnostic methods, we received information about a group of tools that improve the ability of children with ASD to understand and interpret information. Based on the results of psychological diagnostics of children (who participated in the experimental work) using the specified methods, the following results were obtained: the age indicators of children's development relative to the normal population in 21 children with ASD (80%) decreased by an average of 1-3 years. The study of the level of verbal and non-verbal communication is shown in figure 2.

Having analyzed the obtained data, note that 13% of children have severe deviations in verbal communication. They do not use meaningful language. Instead, they utter squeaks, strange sounds, close to human speech. Moderate deviations in verbal communication were observed in 46%. Such children generally lack language. When present, verbal communication is mixed with meaningful or strange language, slight echolalia. A peculiarity in meaningful language is the inclusion of unnecessary questions and interest in certain topics. 41% of children show minor deviations in verbal communication. Language in children is generally formed with a delay. Most parts of the speech are understood, while there is a slight echolalia, incorrect agreement of nouns with numerals, use of cases and pronouns. Sometimes some strange words are used.

According to the results of the study of the level of non-verbal communication, the following results were obtained: 6% have significant violations in non-verbal communication – the child only uses strange gestures that have no obvious meaning and does not understand the meaning of other people's gestures and facial expressions. A significant group of children, 60%, showed moderate deviations in the use of non-verbal communication. Children in general can express their needs and desires non-verbally, but cannot understand the non-verbal appeal of others. Adults are often used as a tool to achieve the desired goal. 34% of children have minor deviations in non-verbal communication. Children demonstrate immature use of non-verbal communication; can only show vaguely or reach for what the child wants, in a situation where a child of the same age normally shows and explains with gestures what exactly he wants.

None of the children knew global reading. It should be noted that 32% of respondents demonstrated knowledge of the letters of the Ukrainian and English languages. Children recognized them in pictures, cubes, laid them out in a certain (at their own discretion) sequence.

At the third – **empirical-synthesizing** – stage, there was an experimental verification of the effectiveness of the developed methodology of using augmented reality for teaching global reading to children with ASD. The technologies of augmented reality that we used in our research are described in our previous publication (Syrovatskyi et al., 2018). The same respondents took part at this stage as at the previous one.

Teaching global reading to children with Autism Spectrum Disorder (ASD) was carried out individually, and augmented reality was created using the Blippar platform. For the initial stage of global reading instruction, the child was presented with the task of recognizing an object, matching it with an image on the picture, and naming it. Afterward, a printed word denoting the object appeared on the screen, which the child had to read and memorize (Task 1). In the subsequent stage, after mastering the reading of nouns, verbs, and adjectives, children were presented with a set of tasks involving reading simple phrases (Task 2) and simple sentences. Examples of tasks for teaching global reading to children with ASD using augmented reality are shown in figures 3 and 4.
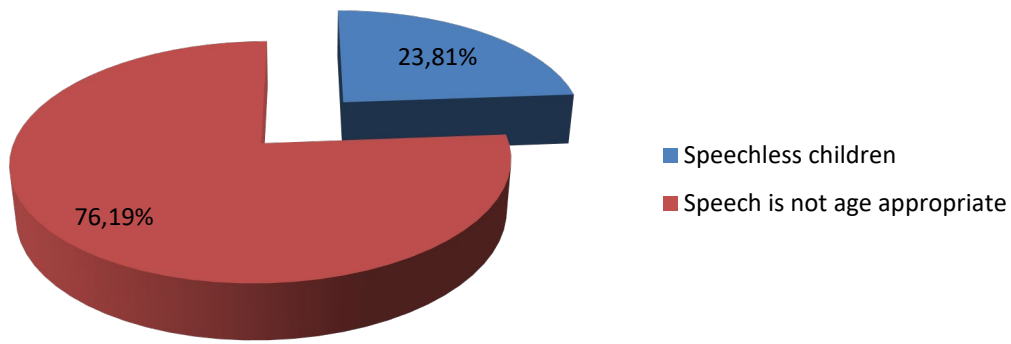
Figure 1: Results of the study of children with ASD according to PEP-R scale.
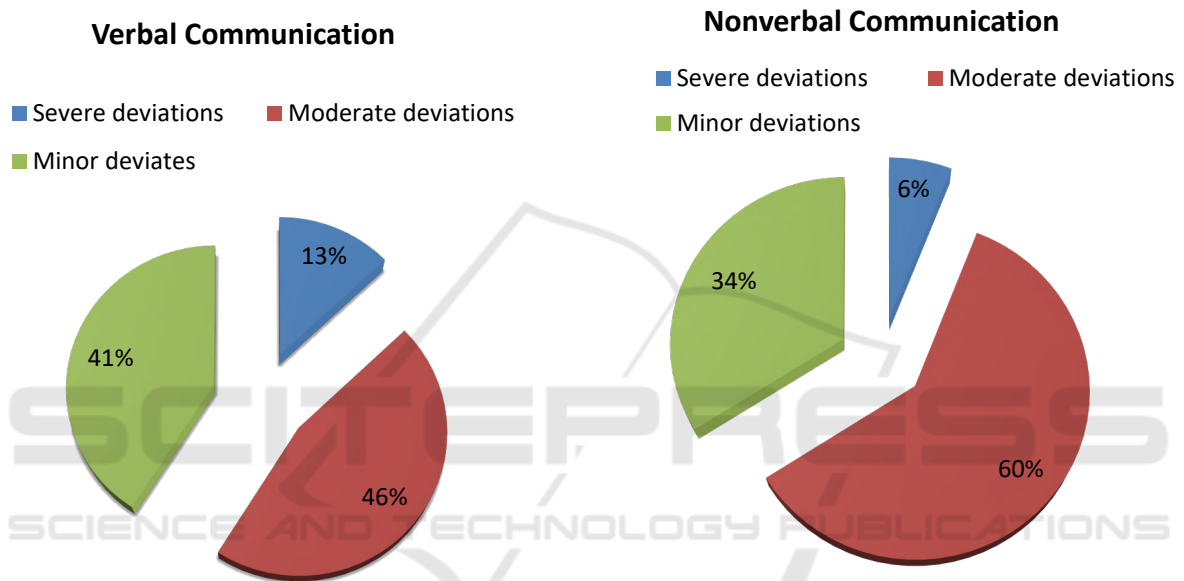

Figure 2: Results of the examination of children with ASD using the CARS method.

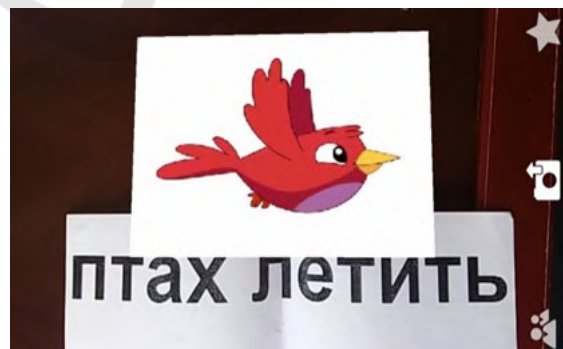Figure 3: Screen capture for Task 1.

Figure 4: Screen capture for Task 2.

Note that a particularly significant result was obtained through the use of augmented reality technology. It should be noted that this technology "combines real and virtual elements with the real world: virtual objects are added to the user's real environment that change as a result of his actions" (Syrovatskyi et al., 2018). Regarding the application of

augmented reality in teaching global reading to children with ASD, we note that the picture began to move, acquire color, volume in the case when the child correctly pronounced the name selected for the picture. It was this tool that stimulated children to work, and formed in them a persistent interest in ver-

Table 3: Results of the annual diagnostics of active speech of children in the research group while implementing corrective measures, %.

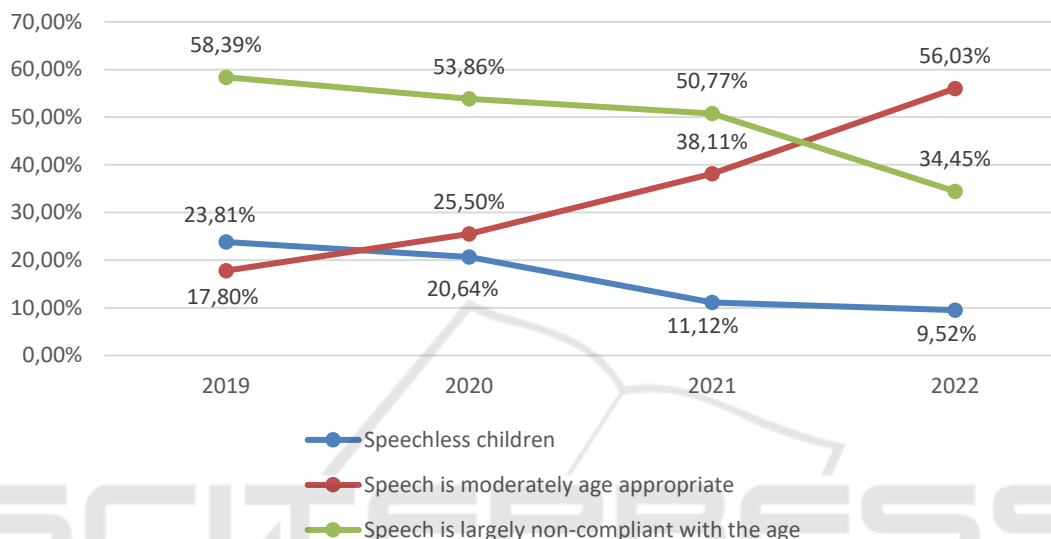| Categories of children	Years				Growth (decrease) rate, %		
	2019	2020	2021	2022	2019-2020	2020-2021	2021-2022
Speechless children	23.81%	20.64%	11.12%	9.52%	-13.31	-46.12	-14.39
Children whose speech is not age appropriate, including:	76.19%	79.36%	88.88%	90.48%	4.16	12.00	1.80
Moderately appropriate	17.8%	25.5%	38.11%	56.03	43.26	49.45	47.02
Largely non-compliant	58.39%	53.86%	50.77%	34.45%	-7.76	-5.74	-32.14

Figure 5: Dynamics of changes in the structure of children with ASD PEP-R according to the active speech criterion.

bal interaction with technology and the teacher. We note that formation of a stable interest in working with digital technology can positively affect the further development, integration and future independent life of children with ASD. After all, it will provide opportunities for obtaining a profession and financial independence.

The fourth – **interpretative-summary** – stage, included diagnostics, analysis and interpretation of the obtained data, summarization of the research results and drawing conclusions.

Thus, the last stage of the work involved rediagnostics using the methods defined during the second stage of the study. The corresponding dynamics of changes in the state of active speech of children with ASD due to the implementation of appropriate corrective and developmental measures, which lasted 4 years (during 2019-2022) are shown in the table 3.

From the data presented in table 3, as well as from figure 4, it can be seen that at the end of the analyzed period, the situation with the number of speech-impaired children improved significantly (their share decreased from 23.81% in 2019 to 9.52% in 2022) (figure 5).

The obtained data are a significant indicator of the effectiveness of the presented methodology. Therefore, it can be argued that the proposed methodology of teaching global reading to children with ASD is a modern technology of visualizing educational information. In our opinion, its use increases the motivation to study, the level of information assimilation due to the diversity and interactivity of its visual presentation, and contributes to the formation of oral speech of a certain category of children.

4 CONCLUSIONS

Thus, the results of the conducted research convincingly demonstrate the effectiveness of the proposed methodology for teaching global reading to children with Autism Spectrum Disorder (ASD) during the use of Alternative and Augmentative Communication (AAC) systems with the utilization of Augmented Reality technology. The suggested algorithm for the formation of the technology for teaching children with ASD global reading comprises the following stages: 1) creating a 'safe' interaction en-

vironment for the child; 2) teaching the child to match captions to pictures (if the child pronounced the word correctly, we offered to 'animate' the picture using Augmented Reality technology); 3) associating verbs with object names (pictograms to pictures); 4) working with individual books: forming sentences and reading aloud; 5) utilizing the Picture Exchange Communication System (PECS) – cards with labels – to reinforce the visual representation of words; 6) employing an Augmented Reality mnemonic table for reading. The developed program for enhancing the effectiveness of teaching global reading to children with ASD using Augmented Reality technology, which includes problem-search, diagnostic, empirically-synthetic, and interpretative-summarizing stages, has proven its effectiveness in practical application. The diagnostic results of children with ASD before and after the experiment confirmed the effectiveness of the proposed methodology for teaching global reading to children with ASD. In particular, there was a significant improvement in the number of non-verbal children (their proportion decreased from 23.81% in 2019 to 9.52% in 2022). In our opinion, this technology plays a crucial role in positively impacting the practice of teaching global reading to children with ASD.

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