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THE LANGUAGE OF IMAGERY AS A COMPONENT OF THE PROFESSIONAL TRAINING OF FUTURE MATHEMATICS TEACHERS

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ABSTRACT

The article examines the concept of the «language of images» as an element of mathematical education, for the perception of abstract mathematical concepts in a visual format, facilitating their assimilation and understanding. The language of images is expressed through its syntax, semantics and pragmatics, as a basis for the formation of the visual subcompetence of the mathematics teacher as a component of information competence. The research addresses retrospective aspects of the use of visual aids in teaching mathematics, describes modern digital tools, their role in the development of critical thinking and their role in the development of the language of images in mathematics education. Special attention is also paid to the strategy of forming future teachers' visual subcompetence as an important component of their information competence, which is based on analysis, creation and interpretation of visual models. Recommendations for the integration of the language of images into pedagogical practice are proposed in order to increase the effectiveness of mathematics education.

Key words: visualization, visual subcompetence, mathematics education, language of images, teacher professional training, digital instruments

INTRODUCTION

In education, the concept of a visual image has long been a means of cognition and communication. Mathematics, as the science of abstract concepts, objects and relations, quite often requires visual embodiment and assimilation. As early as the 70s and 80s of the 20th century, teachers actively used technical teaching aids, such as slides and slide projectors, graph projectors with transparent films, on which mathematical objects and ways of solving problems were depicted with color markers. Codeprojectors, filmstrips and educational film fragments were also used, which made it possible to illustrate the dynamics of mathematical processes. To provide educational institutions with materials, there were even special delivery points where teachers took tapes for film projectors or filmstrips for a certain period of time and returned them after use. The technologies mentioned provided visibility for learning, laid the foundation for the development of modern multimedia technologies, which have become an integral part of the educational process.

Today, the role of graph projectors has been taken over by interactive whiteboards, presentation programs, virtual laboratories and specialized digital environments such as GeoGebra, Desmos, Wolfram Alpha, Mathematica and others. These tools not only reproduce images, but also allow dynamic interaction with mathematical models, combining static visibility with interactive capabilities. The teacher's professional standard, enshrined in a number of documents, in particular in the Order of the Ministry of Education and Culture of Ukraine on the approval of the professional standard «Teacher of General Secondary Education Institution» [1], the State Standard of Specialized Secondary Education [2], in the instructional and methodological recommendations for teaching educational subjects [3], provides mastery of modern teaching methods, effective use of digital tools and integration of figurative presentations into the educational process. Thus, the educational process combines the experience of using visualization and modern digital technologies, meets the legislative requirements and professional standard of the teacher and ensures effective formation of students' competences in mathematics education.

Problem statement

Despite the rich potential of visual aids, their use in practice is often fragmentary, sometimes imposed, overloaded. In some educational institutions, visual materials are used only as auxiliary tools for illustrating individual topics and not as a system-forming component of the educational process. This creates a contradiction between the possibilities of figurative representations and their real embodiment in the study of mathematics. Therefore, the task of the research is to determine the content, structure and functions of the "language of images" as a subcompetence in the professional activity of a mathematics teacher and to develop ways of its formation in the process of training future teachers.

Purpose of the research

The purpose of the research is the theoretical substantiation and disclosure of the content of the concept «language of images» in the context of mathematics education, the definition of its functions and components, as well as the search for ways to form future and current mathematics teachers' visual subcompetence. The research is designed to contribute to the systematization of knowledge about visual learning tools and their role in mathematics education.

Presentation of the main material

The question of visual thinking was raised in various areas of mathematics. Since antiquity, visual models have been used to prove theorems. For example, in Euclid's work «Elements» [4], theorems are accompanied by diagrams that act as a means of prof. Avigad's article «The Role of the Diagram in Euclid's Elements» [5] describes how diagrams provide relationship information and promote understanding. It is worth mentioning Plato, who in his writings interpreted geometric images as a way to understand the problem. Aristotle emphasized the importance of images in the process of forming abstract knowledge [6]. During the Renaissance, Leonardo da Vinci combined artistic and mathematical images, creating visual models of proportions, symmetry and perspective. Further development of visualization ideas can be traced in the writings of René Descartes, who introduced coordinate geometry by combining algebraic expressions with graphic constructions [7]. The theoretical foundations of figurative thinking were described by Clark and Paivio in their work on the theory of double coding [8]. The issue of improving mathematical education, in particular the introduction of visual means for the development of figurative thinking, formation of professional teachers' readiness and integration of information technologies into the educational process, was reflected in the works of a number of Ukrainian scientists. A significant contribution to the development of this scientific problem was made by: L. Bilousova, N. Dehtiarieva, M. Drushliak, V. Vember, N. Zhyiteniova, T. Kolomiiets, P. Mulesa, V. Osadchiy, N. Ponomariova, O. Semenikhina , I. Chorna and others. These researches point to the importance of visualization as a component of teacher's professional competence and emphasize the need for a systematic approach to «language of images» formation in pedagogical practice.

In the context of researching the topic, the language of images is not only a set of illustrations or visual materials, it is also a system of signs and symbols that is a means of thinking, communication and self-expression, transforming abstract concepts in visual forms. Each image used in mathematics (e.g. a graph, diagram, geometric model) acts as a sign that carries a certain semantic load. This «language» allows to briefly submit information without losing content. Its effective use involves formation of a certain subcompetence, visual, which includes the ability not only to create images, but also to «read», analyze and use them effectively in the educational process. Mathematics is an abstract science, and visualization is a bridge between abstraction and a specific image.

Language of images in mathematics education is an effective form of visual media organization based on three key components, syntax, semantics, and pragmatics, which promotes not only knowledge transfer but also the development of students' cognitive and communication skills, allowing them to master complex mathematical concepts through intuitive forms. It, as a system of signs, ensures structuring, transmission and interpretation of information. «The image» in this context is a sign that encodes mathematical information and ensures its availability for further interpretation. For example, the graph of the function $y=f(x)$ is not just an image but a coded system that displays the relationship between variables, their properties and behavior.

Like any language, it has its own syntax, semantics and pragmatics.

The syntax of the «language of images» defines the rules for creating and combining visual elements. This includes standards for constructing graphs (coordinate axes, scale, notation), geometric shapes (points, segments, angles) or diagrams (columns, sectors). For example, a correct graph entry involves clearly marking axes, scales, and critical points, which ensures unambiguity of perception. Incorrect use of syntax, such as incorrect scale or lack of notation can lead to information distortion.

Semantics is responsible for the conceptual apparatus, the meaning of information that is transmitted by visual elements and their relationships. For example, the point of intersection of two graphs symbolizes the solution of a system of equations, and the slope of a straight line reflects the rate of change of quantity. Semantics provides a link between the image and the mathematical concept it represents. For example, in a histogram, the height of a column represents the frequency of a certain event, and in a geometric diagram, the angle between segments can indicate the property of orthogonality.

The pragmatics of the language of images determines the ways of its use in the educational process. It covers students' ability to analyze visual data, create their own models and apply them to problem solving, as well as teacher's ability to effectively use images to explain material and organize educational activities. For example, a teacher demonstrates a diagram, explains the properties of a function or a geometric figure, asks questions so that students draw their own conclusions.

The pragmatic aspect includes reading and interpreting graphs and charts, creating their own visualizations such as flowcharts or models, formulating conclusions based on visual data; and using digital platforms to create dynamic models.

One of the key points of future teacher professional training, in particular mathematics teachers, is formation of visual subcompetence as one of the components of information competence [12], which constitutes the basis of mastery of the language of images. This approach involves the ability to perform semantic compression of information, in other words, to present information in «compressed» form without losing semantic content, transforming mathematical concepts into visual representations. We single out key concepts, cut off the secondary and paraphrase the content for better understanding.

In the context of mathematics, this «compression» takes the form of a visual representation, where, for example, when graphing the function, emphasis is placed on critical points, interval growth or decline, and asymptotes. One of the successful interpretations of the monotony of the function can be an appeal to folk wisdom, for example: "The further into the forest, the more firewood" (literary translation from Ukrainian), «The further you go the worth it gets» (English equivalent).

Let's graph how the amount of firewood increases as you move into the forest. The horizontal axis of the graph in this interpretation corresponds to the forest road, and the vertical one reflects the amount of firewood that can be found on a certain kilometre of the road (see Figure 1).

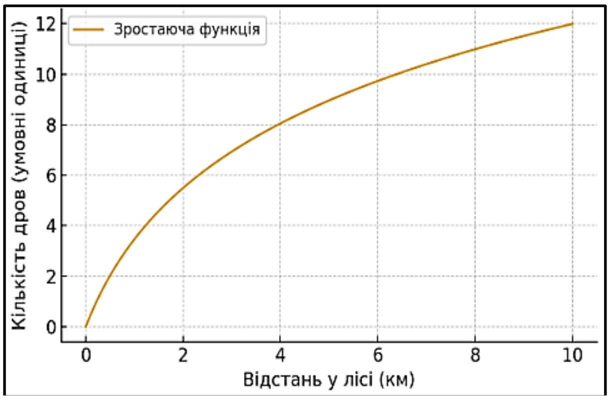

Figure 1. Graph of the growing function (« The further into the forest, the more firewood»)

Similarly, the proverb «You drive quieter – further will be» (literary translation from Ukrainian), "More haste, less speed" (English equivalent) can be given as an example of a decreasing function, where the lower the speed of movement, the longer the path can eventually be overcome (see Figure 2).

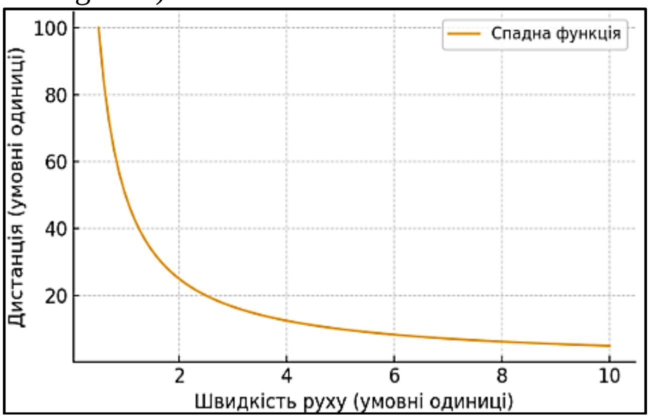

Figure 2. Declining function graph (« Quieter you go – further you will be»)

Such figurative explanations help students intuitively understand the idea of growing and declining functions, and graphs clearly emphasize these associations. This visualization is an example of semantic compression, transformation of an abstract notion of monotony into an intuitive image, sayings that can be described by mathematical dependence. Also, in the form of creative tasks, future mathematics teachers can be offered to independently choose folk sayings and proverbs and display them in the form of graphs. For example, the expression «Above the measure a horse does not jump» (literary translation from Ukrainian) can be interpreted as an example of a bounded function (see Figure 3). If you depict the trajectory of a horse during jumps, then the height of such jumps, in full accordance with the content of the proverb, will be limited from above by a certain limit value (physiological capabilities of the animal, laws of physics, etc.). Such tasks activate creative thinking, develop ability to interpret abstract mathematical concepts in a clear and close form to students, develop visual subcompetence through folk creativity.

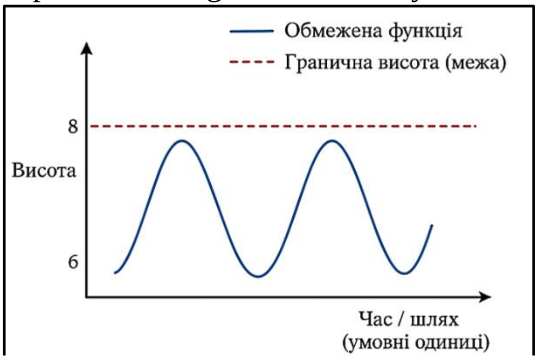

Figure 3. Bounded function graph («Higher than measure horse does not jump»)

Visual subcompetence, as a component of information competence, includes analytical skills (ability to decipher the meaning of graphs, schemes and diagrams), synthetic skills (creating correct visualizations to represent mathematical ideas), transformational skills (modifying images to solve problems or explain concepts), and communication skills (using images to justify conclusions or impart knowledge). Formation of visual subcompetence requires a systematic approach involving both theoretical familiarity with syntax and semantics of images and practical exercises to develop pragmatic skills.

In our opinion, formation of visual subcompetence allows us to present visual information as an active dialogue, where the student not only observes, but understands and interprets the content of what is presented.

Based on the analysis of pedagogical approaches, it is possible to single out a number of strategies for the formation of the language of images, namely:

- working with diagrams, schemes, graphs to identify relations and regularities;
- creating diagrams, drawings or interactive models to represent mathematical concepts;
- comparing textual explanation to corresponding image to form the relationship between a word and an image;
- applying figurative comparisons to explain abstract concepts, which helps activate semantic and visual memory;
- teaching students to explain diagrams or graphs, and how it is related in a mathematical context;
- use of multimedia presentations, digital tools to create dynamic models, which allows to experiment and change parameters in real time.

These strategies are aimed at ensuring that the «language of images» becomes not only a passive way of perceiving information, but a component of educational activity that promotes development of critical thinking and deepens understanding of mathematical concepts, develops ability to correctly understand mathematical content.

Structurally, the language of images can be presented in the form of a gradual accumulation, starting from the elementary level (points, lines, columns, figures, tables), later as a combinatorial level (combination of simple images into complex structures, diagrams, block diagrams, graphs, illustration of dependencies) and as an analytical level (simulation of processes, forecasting of results, search for solutions). Such a structure allows learners to gradually move from simple visual elements to complex ones. In the process of learning, students gradually master the language of images.

An example of the use of image language would be a graph of the function $y = x^2$, on which the vertex, axes of symmetry, points of intersection with axes, and intervals of rise/fall are clearly marked, making it easier to understand the properties of the parabola. Also, one of the classic examples of the use of image language in mathematics is a geometric scheme for proving the theorem on the sum of the angles of a triangle (see Figure 4). This method allows you to clearly demonstrate that the sum of the angles of any triangle is equal to 180°, presenting the proof to a clear visual construction.

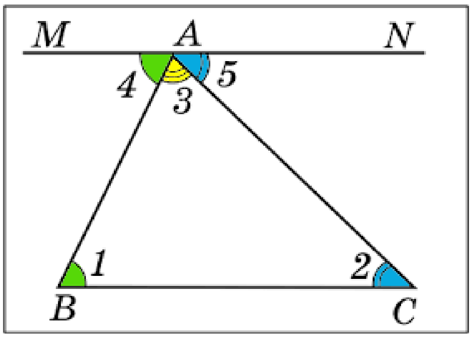

Figure 4 Geometric scheme for proving the theorem on the sum of the angles of a triangle

For the effective implementation of the language of images in mathematics education and formation of future mathematics teachers' visual subcompetence, we offer the following recommendations:

Syntax training. Enter standardized rules for constructing graphs, schemes and diagrams (for example, marking axes, choosing a scale). Provide examples of correct visualizations for learning syntactic norms.

Semantics development. Explain the meaning of visual elements through analogies (for example, a graph as a «map» behavior function). Conduct exercises to compare images with mathematical concepts.

Pragmatics training. Set tasks to create visualizations (for example, graphying a schedule for data sets or creating a block diagram for an algorithm). Use interactive tools, online services e.g. with dynamic models.

Visual subcompetence formation. Include modules on the development of skills in creating, analyzing and interpreting visual models in the educational programs of pedagogical universities. Organize practical sessions where future teachers create their own visualizations and explain their relationship to mathematical concepts or real-life examples [14]. Implement assessments that include creative tasks to analyze, create and interpret visualizations, as well as test the ability to explain practical, real life situations and one's own visual models.

Integration of digital tools. Teach future teachers to use modern platforms (GeoGebra, Desmos, Wolfram Alpha, etc.) to create interactive models. Develop skills in adapting digital tools to the needs of a specific lesson or task.

CONCLUSION

The language of images in mathematics education is a modern and powerful tool for structuring, transferring and assimilating knowledge through visual means. It is based on syntax, semantics and pragmatics, which ensure its functionality as a system of signs. Formation of visual subcompetence is a key to the effective use of this language, allowing transformation of abstract mathematical concepts into understandable images. Systematic implementation of the concept of the language of images in the educational process, in particular through the use of digital tools and practical tasks, contributes to increasing the learning effectiveness, development of critical and creative thinking and formation of modeling skills.

In the professional training of future mathematics teachers, special attention should be paid to the development of information competence and its component of visual subcompetence through purposeful teaching of syntax, semantics and pragmatics of the language of images. The integration of modern digital tools and practical strategies, such as creation of interactive models and comparison of textual and visual representations, allows teachers to develop the skills necessary for the effective use of visualization in pedagogical practice. We plan to direct further research to the development of specific methods for assessing visual subcompetence and analyzing its impact on the quality of mathematics education.

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