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RESEARCH ARTICLE

FORMATION OF SPATIAL THINKING OF FUTURE ENGINEERS ON THE BASIS OF FUNDAMENTAL GRAPHICS TRAINING

Nina I. Krasovskaya*, Natalia V. Bauer, Irina V. Shusharina, Anna A. Romanova

Tyumen Industrial University, 38 Volodarskiy Str., Tyumen, Russian Federation
****Corresponding Author Email:*** krass51@mail.ru

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ABSTRACT

The level of graphics training in an engineering higher school is the most important characteristic of the skill of the graduate. The period of formation of professional readiness of a specialist is closely connected with the study of descriptive geometry, engineering graphics, computer graphics and other graphics disciplines. Geometric interpretation of phenomena in any form practically permeates the entire system of educational disciplines, both the general engineering cycle and special cycles of engineering education. Spatial thinking is formed only on the graphics basis, which is the basis of the student's design abilities. Since the main tool for the formation of spatial thinking is graphical visual aids, the basis for its formation is the solution of problems presented on the basis of various types of graphic images (drawings) that reflect the spatial characteristics of objects in conventions (lines, signs). Introduction of tasks of the experimental methodology to the educational process has a positive impact on the quality and strength of knowledge on the subject, on memory productivity and on increasing the level of spatial thinking, which ultimately positively influences the formation of the engineer's professional thinking.

KEYWORDS

Interactive methods of teaching, spatial thinking, technology of project-based learning, graphic images.

1. INTRODUCTION

The conditions of the modern world are such that for society to successfully adapt to them and effectively continue to function, it is necessary to include an increasing number of people who are creative, capable of free orientation and productive self-realization in the conditions of the market and rapid social changes. Such a need must be met by professional training oriented to the model of a specialist (qualified, competent, competitive) which will undoubtedly be characterized by a person's readiness for continuous self-improvement, self-awareness, the ability on this basis to quickly reorient from the usual ideas to an active perception of new, unconventional, and, finally, to an active transformation of the conditions of life, creation of new ones, and adaptation to them [1]. The basis of all these abilities will definitely make up the general intellectual development, especially its leading substructure – thinking.

During studying at a university, when a solid basis of work activity is formed, special professional thinking begins to develop. This is an important aspect of the process of professionalization of a person and a prerequisite for the success of the professional activity, an integral part of the vocational education system. The current pace of development of information technology in all areas of production requires a fundamental graphic preparation. Effective implementation of the project activity depends on the special preparation of students, understood by us as a set of external and internal conditions that allow solving problems competently and responsibly in the field of design. Spatial thinking is formed only on the graphic basis, which is the basis of the student's design abilities. For this, it is necessary that the students of technical universities master a complex of graphic knowledge, abilities, and skills [2].

2. RESEARCH METHODS

The methodological basis of the research was pedagogical studies of the features of the formation of the socially active, creative personality of students; a dialectical understanding of project creativity as an activity that generates something qualitatively new; an innovative approach to the problem of the professional formation of the future engineer [3].

To solve the tasks, a set of the following methods was used: analysis of pedagogical, methodological and special literature; generalization of pedagogical experience of teachers of higher education and their own work in the university; observing the course of students' academic activity and teaching special disciplines; conversations; analysis of students' work; testing and questioning; conducting pedagogical experiment [4].

To form spatial thinking, the student must develop the ability to identify the problem and formulate the task, the ability to think figuratively, freely formulate thoughts and verbally express them. It should be noted that in the process of teaching the teacher should "design" the student's thinking in such a way that, understanding the structure of the design process, he could build such an algorithm of actions that can adequately respond to the project situation and change in the right direction if necessary [5]. Ability to think abstractly and in general, in our opinion, is extremely important and is an indispensable element that forms spatial thinking. The result of training is a qualitative change in thinking, consciousness, the whole psyche and the personality of the learner. This new acquisition does not only add to everything that has been before but fundamentally transforms it to a new level of functioning [6].

The formation of spatial thinking is directed to the development of logical forms of thinking: project concepts, judgments, inferences, analogies. The term "spatial thinking" refers to a rather complex process, which includes not only logical (verbal-conceptual) operations, but also a set of perceptual actions, namely: identification of objects represented in real terms or depicted by various graphic means, creating adequate images on this basis and operating them in the process of solving the problem. Spatial thinking

is a specific kind of mental activity aimed at solving problems that require orientation in practical and theoretical space (both visible and imaginary). In its most developed forms, this is thinking by images in which spatial properties and relationships are fixed. Using initial images created on a different graphic basis, thinking provides for their transformation and creation of new images that are different from the original ones.

Spatial views of students in the learning process are predominantly formed by:

1. Observation.

2. Perceptions and comprehension of information received from the teacher and from literature.

3. Practical activities (measurement, construction, modelling, problem solving, etc.)

4. Mentally operating spatial representation.

The structure of spatial thinking is determined by a combination of conditions, including:

1. Nature and content of the visual basis on which a spatial image is created;

2. Features of a graphical task that defines the requirements for creating an image and operating it;

3. Presence of certain representation methods that provide a productive (or less productive) transformation of visual material [7].

To study the influence of these conditions on the formation of the structure of spatial thinking with given properties, sets of experimental tasks were developed, and in individual experiments, their effectiveness was identified in accordance with the goals and tasks set. For example, one or several types of graphic tasks were chosen, in which a transition from a two-dimensional image to a three-dimensional image was envisaged, from a visual to a schematic one.

1. Construct a reflection of the point in the ABCD plane of the mirror (the point and its reflection are symmetric with respect to the plane of the mirror), Figure 1.

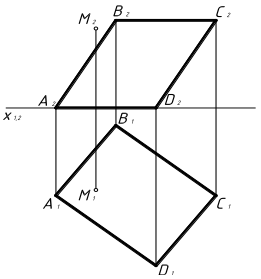

Figure 1: The point and its reflection are symmetric with respect to the plane of the mirror

2. Construct a line of intersection of the open torus with the front-projecting plane P and show the visibility of this line, Figure 2.

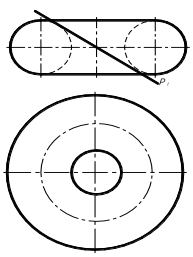

Figure 2: A line of intersection of the open torus with the front-projecting plane P

3. Construct a profile projection of the surfaces with the given cut-outs, Figure 3.

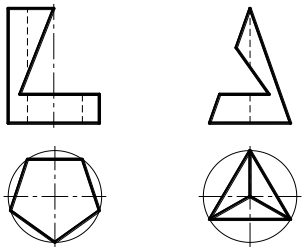

Figure 3: A profile projection of the surfaces with the given cut-outs

4. Construct intersection lines of the surfaces, Figure 4.

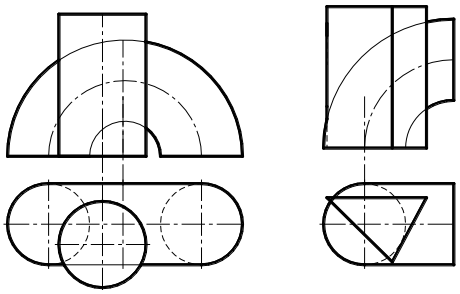

Figure 4: Intersection lines of the surfaces

5. Construct a profile projection of the object and its visual image, Figure 5.

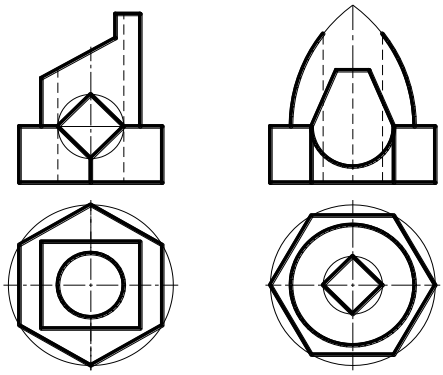

Figure 5: Profile projection of the object and its visual image

Teachers have developed methods of organizing classes that can significantly improve the level of spatial thinking [8]. On the basis of theoretical and experimental studies to determine the formation of the spatial representation of students, its completeness, meaningfulness, reality, scientific character, we propose the following skills as a rating criterion:

1. Recognize this object among objects of reality.

2. Recognize the object among images.

3. Establish the relationship between the word, the representation of the image and the object of reality.

4. Reproduce the object in the imagination (memory representation).

5. Reproduce memory representations (verbally, graphically, as a model).

6. Create new objects in the imagination (imagination representation).

7. Reproduce imagination representations (verbally, graphically, as a model).

On the basis of these skills, the levels of formation of spatial thinking of students were determined. To increase the level of development of spatial thinking means to increase the level of development of professional abilities [9].

3. RESULTS

Before conducting the practical work, a conversation is held with students during which they get acquainted with the set of requirements, with the criteria for assessing the work. After the experiment, the students were acquainted with the research data. The study was conducted with students of the first year. Concluding the analysis of students' work, test assignments, we highlight those moments that are determining in finding ways to improve the effectiveness of forming spatial thinking of students:

3.1 Level I (Accumulative)

Accumulation and recognition of spatial features and relationships. Students accumulate a variety of spatial representations, learn to recognize a variety of spatial objects, their individual characteristics, and relationships. They can give a name of the object, find it in the picture among objects of reality. But the differentiation between different categories of spatial features is unstable, often there is no correspondence between the image and the word and vice versa. Representations of students are incomplete.

3.2 Level II (Reproductive)

Reproduction of the memory representation. Students have the ability to reproduce (in representation – verbally, in the picture – as a model) spatial features and relationships known to them. The stock of spatial terminology has been increased, various kinds of spatial representation and relations have been accumulated: students are able to establish connections between space, quantities and time representations. The word already acquires a signal meaning and generates a corresponding representation.

3.3 Level III (Constructive)

Independent construction of a spatial image. Students actively use already formed representations in the synthesis with quantitative and temporal relations as a support in the thinking activity. They are able to give a verbal description of spatial attributes and relationships relying on individual elements of spatial concepts (form, value, distance, etc.). Based on formed spatial representations, they create new representations and operate them using verbal descriptions, numerical data, and drawings.

3.4 Level IV (Intellectual)

Mental operation with spatial representations. Students have a rich stock of spatial representations, terminology, they easily differentiate spatial attributes and relationships. This level is characterized by the ability to mentally move spatial objects (symmetry, transfer, rotation), find the position of the figure in the picture after its displacement, the type of displacement, etc. [10].

All levels are closely interrelated, intertwined, and one can assume that each preceding one is the base for the successor. Raising the levels of spatial thinking, the teacher raises the level of formation of the professional spatial thinking of students. In the formation of spatial thinking, levels of formation can coexist when operating different content by the same students and the same content by different students [11]. A special place in the formation of representations is given to reading and constructing graphic images. When constructing a graphic image, the main task is to translate the representation of an object into its image on the plane, while reading solves the opposite problem: on the basis of perception of the image on the plane, the shape, dimension, position of the object in space are mentally reproduced and the necessary information, relationships, and relations are clarified.

Representations about an object when reading and constructing graphic images are formed not only as a result of direct recognition or recall but as a result of an entire system of mental actions aimed at transforming the data of perception and the mental reproduction of the image. Reading and constructing cannot be reduced directly to skills, they are meaningful abilities in which only individual actions are automated [12]. To increase the level of spatial thinking, a model of a methodological system for the formation of spatial thinking of students in classes on Descriptive Geometry was developed.

The methodological system has the following goals:

- development of spatial thinking, visual-graphic memory among students;
- mastering of technical abilities and design skills and successful application of these skills in the creation of projects;
- formation of interest in project activities.

The development of students' spatial thinking is achieved under the following conditions:

- the teacher sets purposeful and methodically consistent tasks on the development of spatial thinking;
- development of visual memory, imagination, artistic and imaginative vision;
- use of methods and forms of organization of classes aimed at activating students' spatial thinking and their cognitive interest;
- formation of an emotional-value attitude to one's own work.

Three levels of development of spatial thinking are singled out: low, medium, high.

3.5 Low level

Students have little theoretical knowledge and are struggling to cope with educational tasks. They have a poor imagination. In many cases, the low level of imagination and technical difficulties dictate the fact that their creative initiative is reduced to zero. Because of this, their works are not accurately executed, the tasks are poorly or practically not solved.

3.6 Medium level

Students who have a medium level of development of spatial thinking conscientiously fulfil tasks, but their creative initiative is not often manifested in independent work. Their imagination still has a poor experience and is therefore limited and not productive enough.

3.7 High level

Students with a high level of development of spatial thinking cope with the tasks quicker and are able to find several options for solving learning and creative problems.

In this study, the following diagnostic methods were used: observation, questionnaire, analysis of the results of learning and creative activity of students, testing. The following forms of the organization of classes were used: lectures, practical classes, consultations; organization of academic competitions, conferences. In this model of spatial thinking of students in the process of studying the discipline "Descriptive Geometry" the following methods were used:

- **explanatory-illustrative method –** lecture, story, work with literature, etc.;
- **heuristic method** – the teacher does not give the ready knowledge, but sets before the students the educational problem of one or another level, then, by means of successive study assignments, leads the students to its independent solution;
- **research method** – research activities of students are possible on two levels:

– training and research – working with primary sources, carrying out experiments, accumulating data for building tables, graphs, diagrams;
– research – own logical conclusions, suggestions for carrying out the experiment and interpretation of its results;

- **method of group discussion** – collective discussion of the observed object, based on a certain sequence of questions asked by the teacher (discussion of any emerging problem with the participation of the whole group);

- **method of business games** ("roundtable", "brainstorming") – imitation and game modelling, contributing to the achievement of many goals of professional training and a socially active position.

The training means are: a system of tasks and exercises, textbooks, posters, breadboard models, models in wood and metal, technical means, computer illustrations. This includes information technology, which involves the use of information and educational resources: text materials, computer training programs, multimedia products of the educational field. Formation of spatial thinking of students in the process of professional training is impossible without one of the most important technologies of problem training – the project method [13-15]. The project method is focused on the independent creative activity of students: individual, pair or group. The result of the analysed model is a transition of the student from one level of formation of spatial thinking to a higher, qualitatively different level compared to the previous level (Table 1).

Table 1: Model of the methodological system for the formation of spatial thinking of students in classes on Descriptive Geometry

Goal: formation of professional thinking of students in classes on Descriptive Geometry				
Objectives: increase in the level of the formation of professional thinking of students				
Principles				
Accessibility	Visibility	Scientific nature	Consistency	
Levels of formation of professional thinking of students				
Low		Medium	High	
Diagnostic methods				
Observation	Questionnaire	Performance analysis	Conversation	Testing
Forms				
Lectures	Practice work	Test		Academic competitions
Means				
System of tasks	System of exercises	Guidelines	Technical means	Visual aids
Methods				
Explanatory-Illustrative	Heuristic	Research		Group discussion
Pedagogical technologies: project method				
Modern teaching systems – pedagogy of cooperation				
Result: transition to a new level of the formation of spatial thinking of students				

4. CONCLUSION

The results of the experiment indicate that:

- in the traditional conditions of the work of higher education, the level of the formation of spatial thinking among students remains relatively low;
- to more effectively increase the level of formation of spatial thinking of students, a new methodology needs to be introduced and appropriate implemented;
- the implementation of the model of the methodological system contributes to the achievement of the highest result – an increase in the level the formation of spatial thinking of students.

The formed spatial thinking of students within the discipline "Descriptive Geometry" is considered as the basis for the development of special abilities, it is a prerequisite for the successful mastery of scientific, technical, design and other activities related to design thinking and technical creativity.

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