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Modular technology of formation of spatial representation and perception, constructive and geometrical thinking among university students

Metodología modular para el desarrollo de la percepción espacial e imaginación, así como del pensamiento contructivo y geométrico de los estudiantes universitarios

Dmitriy G. MIROSHIN 1; Natalya V. BORODINA 2; Natalya N. MICHUROVA 3; Valeriy B. POLUYANOV 4; Alexey V. KRIVTSOV 5; Nadezhda S. KONOVALOVA 6

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Contents

ABSTRACT:
The relevance of the studied problem is caused by a tendency of development of practice-oriented training of engineers and bachelors in the technical directions of training. The constructive and graphic preparation is directed to formation of the spatial perception and representation and constructive and geometrical thinking promoting development of students abilities of modeling and designing of real technical objects. The purpose of the presented article consists in the description of a modular technology and methodical providing directed to formation of spatial representation and perception, and also constructive and geometrical thinking and results of experimental approbation of the developed technology in the conditions of university when training engineers and bachelors of the technical specialties.
Keywords: Spatial representation and perception, constructive and geometrical thinking, indicative scheme of actions, modular technology, educational

RESUMEN:
La relevancia del problema investigado, está motivado por la tendencia del desarrollo de la preparación práctica y orientada a ingenieros y licenciados en ramas técnicas de la educación, donde uno de los aspectos estudiados es la preparación gráfico-constructiva orientada al desarrollo de la percepción espacial e imaginación, pensamiento constructivo y geométrico, promoviendo el desarrollo de habilidades para la modelación y diseño de objetivos técnicos. El propósito del artículo consiste en describir la metodología modular y el apoyo metodológico orientados al desarrollo de la percepción espacial e imaginación, igualmente, del pensamiento constructivo y geométrico y del resultado de los ensayos experimentales.
Palabras clave: Percepción espacial e imaginación, pensamiento constructivo y geométrico, esquema indicativo de acciones, enfoque modular, elemento educativo

element	

1. Introduction

One of the directions of development of professional and significant qualities of the identity of a future worker, an engineer, a teacher of vocational education is the formation of spatial representation of technical objects which are often presented in the form of two-dimensional models on working and assembly drawings, schemes, sketches, and also are described by the parametrical equations, for example, the equations of kinematic balance during the analysis of kinematic schemes. Students receive primary idea of features of modeling and parametrical description of technical objects during studying of the educational subject "Descriptive Geometry and Computer Engineering Graphics".

The problem of formation of spatial representation and perception, and also constructive and geometrical thinking in educational space of university is considered in works of V.A. Gerver (1970), E.L. Surin (1972), N.V. Kaygorodtseva (2014), V.G. Sereda (2009). The features of the choice of pedagogical technologies of development of spatial representation and perception, and also constructive and geometrical thinking are considered in works of O.V. Yaroshevich & N.V. Zelenovskaya (2014), N.E. Suflyaeva (2015), N.A. Salkov (2016), V.V. Utemov & A.R. Masalimova (2017).

Theoretical aspects of formation of an approximate basis of actions are provided in the studies of P.Ya. Galperin (1998), N.F. Talyzina (1998). High potential for formation of spatial representation and perception, and also constructive and geometrical thinking in educational space of university lies in the modular technology of training which theoretical and application-oriented aspects are considered in the studies of E. Crochet (1998), P.A. Juceviciene (1989), N.V. Borodina & N.E. Erganova (1994), N.G. Kalashnikova & M.V. Borzov (2011), V.A. Degterev (2014), E.N. Yarkova (2015).

The purpose of the educational subject "Descriptive Geometry and Computer Engineering Graphics", studied at university, is development of spatial representation and perception, constructive and geometrical thinking that define the abilities of trainees to the analysis and synthesis of spatial forms and relations on the basis of the graphic models of space which are almost realized in the form of drawings of specific spatial objects and dependences.

Acquisition of skills of an image of specific spatial objects on the plane is one of the main difficulties which students of the first year of training meet. Forming of ability of accurate and correct drafting of spatial objects requires long exercises. However, spent for this time pays off further while solving quite complex design tasks as a visual demonstration which is correctly performed by a student helps to understand an essence and a sense of a design task, to reveal and find the solution of various theoretical questions relating to the set design task and, as a result, to find an algorithm of the decision and to offer versions of the solution of the set design task. Therefore, the main objective of studying of the educational subject "Descriptive Geometry and Computer Engineering Graphics" comes down to studying of methods of creation of the certain graphical models of space based on orthogonal projection and ability to solve on these models the tasks connected by spatial forms and relations.

2. Methodological Framework

Theoretical aspects of forming of spatial representation and perception, constructive and geometrical thinking determining capabilities of trainees to the analysis and synthesis of spatial forms and relations on the basis of graphical models of space are considered in works of A.D. Botvinnikov (1981), N.V. Kaygorodtseva (2014), N.E. Suflyaeva (2015), O.L. Luneeva & V.G. Zakirova (2017), P.M. Gorev et al. (2017), P.M. Gorev & A.M. Kalimullin (2017), Z.V. Shilova & T.V. Sibgatullina (2017). Based on works of the noted authors, and also the works of V.P. Bespal'ko (1989), we believe that it is possible to allocate three levels of formation of spatial representation, perception and constructive and geometrical thinking: reproductive, productive and creative.

At the reproductive level trainees are capable to solve standard problems on creation of

graphical models of space based on orthogonal projection (level of reproductive abilities).

At the productive level trainees are capable to use methods of transformation of graphical models of space on the basis of the abilities of the solution of standard tasks of reproductive level which are available for them on creation of the graphical models of space based on orthogonal projection (level of demonstration of abilities).

At the creative level trainees are capable to solve creative problems according to the analysis and synthesis of the spatial forms and relations based on methods of transformation of graphical models of space, to search the methods of transformation of spatial models depending on specific spatial objects (creativity level).

We believe that forming of spatial representation and perception, constructive and geometrical thinking is possible to be conducted in two stages. At the first stage the approximate scheme of actions according to the solution of standard graphical tasks of reproductive level is created among trainees during independent studying of an educational element on a subject. At the second stage, based on the approximate scheme of actions fulfilled at independent work, trainees solve graphical problems of productive and creative level depending on complicacy of the subject.

We suppose that the modular technology of training described in the works of E. Crochet (1998), A.V. Krasnuik & T.V. Tatiana (2011), etc, has high potential for the similar organization of an educational process.

It is possible to allocate two main approaches to the organization and implementation of the modular training: system-activity and subject-activity.

Within the system-activity approach opened in the concept of Modular Employable Skills (MES concept) and developed by the International Labour Organization, the modular program is formed on the basis of the analysis of professional activity of trainees, and each logically complete operation of professional activity is adequate in the program to one modular block which reveals further the sequence of steps of performance of operation of professional activity and the skills necessary for performance of each step (Zareena & Haider, 2013; Lin, Sokolova & Vlasova, 2017; Liu, Utemov & Kalimullin, 2017). Educational elements of various categories are brought into accordance with the marked-out skills (category 01 – safety of work, 02 – activity, 03 – the classical theory, etc.), and each step comes to the end with studying of an educational element of category 02 activity and consists in performance of a practical task. Consistently studying educational elements of various categories, students hone basic skills, master steps and, finally, master all operation of a professional activity.

Within the context of the subject-activity approach opened in works of P.A. Juceviciene (1989), N.V. Borodina & N.E. Erganova (1994), etc., the modular program is also formed on the basis of the analysis of professional activity. The allocated modular blocks reveal in the modular maintenance of educational subject studied during the development of an educational program. The educational program is under construction according to logic of the carried-out professional activity and substantially reflects the sequence of the solution of tasks arising during performance of a professional activity.

Comparing both approaches to the organization and implementation of the modular training, it is possible to draw a conclusion that it is expedient to use the technology of modular training based on the subject-activity approach in the system of the higher and secondary professional education, and also at advanced training courses of engineering and pedagogical staff. Therefore, we believe that the organization of process of the training directed to formation of spatial representation and perception, constructive and geometrical thinking is possible at application of subject and modular approach to the organization of educational process for the educational subject "Descriptive Geometry and Computer Engineering Graphics" which is described in the works of N.V. Borodina & N.E. Erganova (1994), P.A. Juceviciene (1989).

At the same time, according to P.A. Juceviciene (1989), the module is understood by us as a logically complete part of an educational subject corresponding to one topic. Thus, based on the analysis of literary sources and the experience of modular technologies use of training in

Russia and abroad, we have stopped on the subject and modular organization of an educational process for the educational subject "Descriptive Geometry and Computer Engineering Graphics".

During the research the following methods were used: experimental and theoretical (analysis, synthesis, deduction and induction), diagnostics methods (analysis and diagnostics of level of formation of spatial representation, perception and constructive and geometrical thinking on the basis of the analysis of graphic works of students), empirical methods (forming pedagogical experiment, comparative pedagogical experiment), methods of mathematical statistics for assessment of reliability of the received results and methods of graphical representation of research results.

The pilot study was conducted at the Russian State Vocational Pedagogical University when training bachelors in the Vocational Education direction (branch Mechanical Engineering and Materials Processing), and also at the Ural Institute of State Firerfighting Servise of EMERCOM of Russia during training of cadets on specialties "Fire Safety" and "Technosphere Safety".

The research was carried out in 5 stages:

1. Determination of the problem field of the research and problem statement of the research.

2. Overview and analysis of sources of information on the research problem.

3. Forming of a complex of methods of the research according to the formulated research problem.

4. Development of educational and methodical materials for carrying out experimental works.

5. Carrying out the creating and comparative experiment, the analysis of the obtained experimental data, assessment of results of the research and forming of conclusions.

3. Results

Problem statement. The task of development and experimental approbation of the modular technology of formation of spatial representation and perception, constructive and geometrical thinking based on subject and activity approach on studies of the educational subject "Descriptive Geometry and Computer Engineering Graphics" was set in the research, and in the course of the organized independent work which would allow to create among trainees the creative level of the solution of graphic tasks of the analysis and synthesis of the spatial forms and relations focused on the ways of transformation of graphic models of space.

Each module is provided with the corresponding methodological support: materials for lecture and practical training, independent work of trainees, and also control of level of formation of spatial representation and perception, constructive and geometrical thinking.

Methodological support of the modular technology. The structure of methodological support of the module on the topic involves: lecture material accompanied with the multimedia presentation; educational element reflecting a technology of performance of a standard graphic task used as means of formation of an approximate basis of activity during independent work; package of graphic tasks of creative level intended for performance by trainees on seminar occupation. The educational element was the main means for independent work of trainees. The educational element is represented in the form of a brochure which consists of the coordinating, informatiive-activity and supervisory parts.

The coordinating part has been intended for coordination of trainees in the field of the purposes of studying of an educational element, the equipment and tools necessary for its studying, and also in the field of the list of the educational elements preceding this educational element.

Informativeand-activity part of an educational element consisted of two columns: the complete text paragraphs representing an algorithm of performance of a task are provided in the left column; in the right part the basic drawing illustrating the algorithm step

described in the paragraph is brought in line with each text paragraph.

The supervisory part of an educational element represented the list of control tasks with forms of answers which students filled after studying of an educational element, and also a model of performance of the graphic task described in an educational element.

Modular technology. Educational process on studying of each module has been included in the general system of occupations in higher education institution and had the stage-by-stage organization. A two-hour lecture was given at the first stage of studying of the subject. Theoretical provisions on this subject with use of multimedia systems were considered in detail during the first hour of the lecture; the practical application of the studied training material was revealed.The second hour of the lecture was devoted to detailed studying of the educational element focused on performance of a standard graphic task on the studied subject. The second stage consisted in independent work of students; they studied an educational element and performed a standard graphic task by the technology stated in an educational element. At the same time, the following sequence of work with an educational element was recommended to students:

1. To read the purposes of studying of an educational element, to prepare necessary drawing tools, sheets of paper of the set format.

2. Being guided by the abstract of educational class, to study the corresponding training material according to the textbook offered by the teacher as the basic of the considered subject.

3. To refer to the given educational element and use it. The trainee is offered to study consistently the text material stated in substantial paragraphs on the left of an educational element; the students analyze the illustration corresponding to the studied paragraph along with studying of text material and establish compliance between text material and its graphic display in the right part of an educational element.

4. To close a test part of an educational element and to reconstruct the content and a technology of performance of a graphic task using the illustrations given in the right part.

5. To take the prepared sheet of paper of the appropriate format, to prepare the drawing tools given in the description of the equipment on the coordination page of an educational element.

6. To close the right (illustrative) part of an educational element. Using the work performance technology described in a text part of an educational element, to perform a graphic task on an educational element.

7. Having finished performance of a task, to compare the graphic representation received on a sheet of paper to the image provided in the controlling part of an educational element; to reveal possible mistakes, and being guided by an illustrative part of an educational element to correct them.

8. To turn to the questions for self-checking given in the controlling part of an educational element and to answer them, filling the corresponding form of the answer.

The standard graphic tasks and forms of answers completed with use of an educational element were checked by the Leading Teacher of the Department in strictly certain terms, usually within seven days after holding a lecture on the studied subject.

The third stage has been directed to formation of a creative level of performance of graphic tasks and was implemented on seminar or discussion session. During an educational seminar each student received own variant of performance of a creative educational task according to the image of various graphic objects on drawings. Performance of creative tasks promoted active intellectual potential of students, forcing them to look for solutions of non-standard tasks on the basis of the indicative scheme of activity created during studying of an educational element.

Thus, during the third stage students performed creative graphic tasks that has caused formation of abilities to think "outside the box" and apply the available knowledge and abilities in a new practical situation, development of informative activity and creativity, and, as a result, promoted formation of creative level of perception of space and development of

spatial representation and perception, constructive and geometrical thinking.

Experimental approbation of the modular technology and methodological support. Experimental approbation of the described technology of formation of spatial representation and perception, constructive and geometrical thinking was carried out during studies of the educational subject "Descriptive Geometry and Computer Engineering Graphics" applied at the Russian State Vocational Pedagogical University when training bachelors in the direction Vocational Education (branch "Mechanical Engineering and Materials Processing") and during studies of the educational subject "Descriptive Geometry and Engineering Graphics" in the Ural Institute of State Firerfighting Servise of EMERCOM of Russia during training of cadets on specialties "Fire Safety" and "Technosphere safety".

Four groups of students of the Russian State Vocational Pedagogical University and four groups of cadets of the Ural Institute of State Firerfighting Servise of EMERCOM of Russia have taken part in experimental approbation. The total of participants of experimental approbation amounts 180 people.

The criteria for evaluation of a level of formation of spatial representation and perception, constructive and geometrical thinking of trainees and in particular have been worked out during the experimental approbation, inclidung:

- reproductive level was estimated in the range from 0 to 10 points;

- productive level was estimated in the range from 0 to 20 points;

- creative level was estimated in the range from 0 to 30 points.

The range of points was determined for assessment of completeness and correctness of accomplishment of a graphical task.

The experimental approbation included the stating, creating and control phases.

The stating phase of experimental approbation was conducted by means of test techniques and a package of control tasks. The initial level of formation of spatial perception of four groups of students and four groups of cadets has been revealed; an average value of level of formation of spatial perception, constructive and geometrical thinking of students and cadets has been calculated. Two control and two experimental groups with the close level of formation of spatial representation and perception, constructive and geometrical thinking have been created by the results of the stating phase.

The comparative experiment was carried out during one semester. The following educational subjects were studied during the experiment:

- "Projection of Straight Lines";

- "Projection of Planes";

- "Ways of Transformation of Projections";

- "Axonometrical Projections of Straight Lines and Planes";

- "Projection of Solids. Development of a Surfaces of Solids";

- "Crossing of Solids. Creation of İntersection Lines by Method of Auxiliary Secant Planes";

- "Crossing of Solids. Creation of İntersection Lines by Method of Auxiliary Secant Spheres".

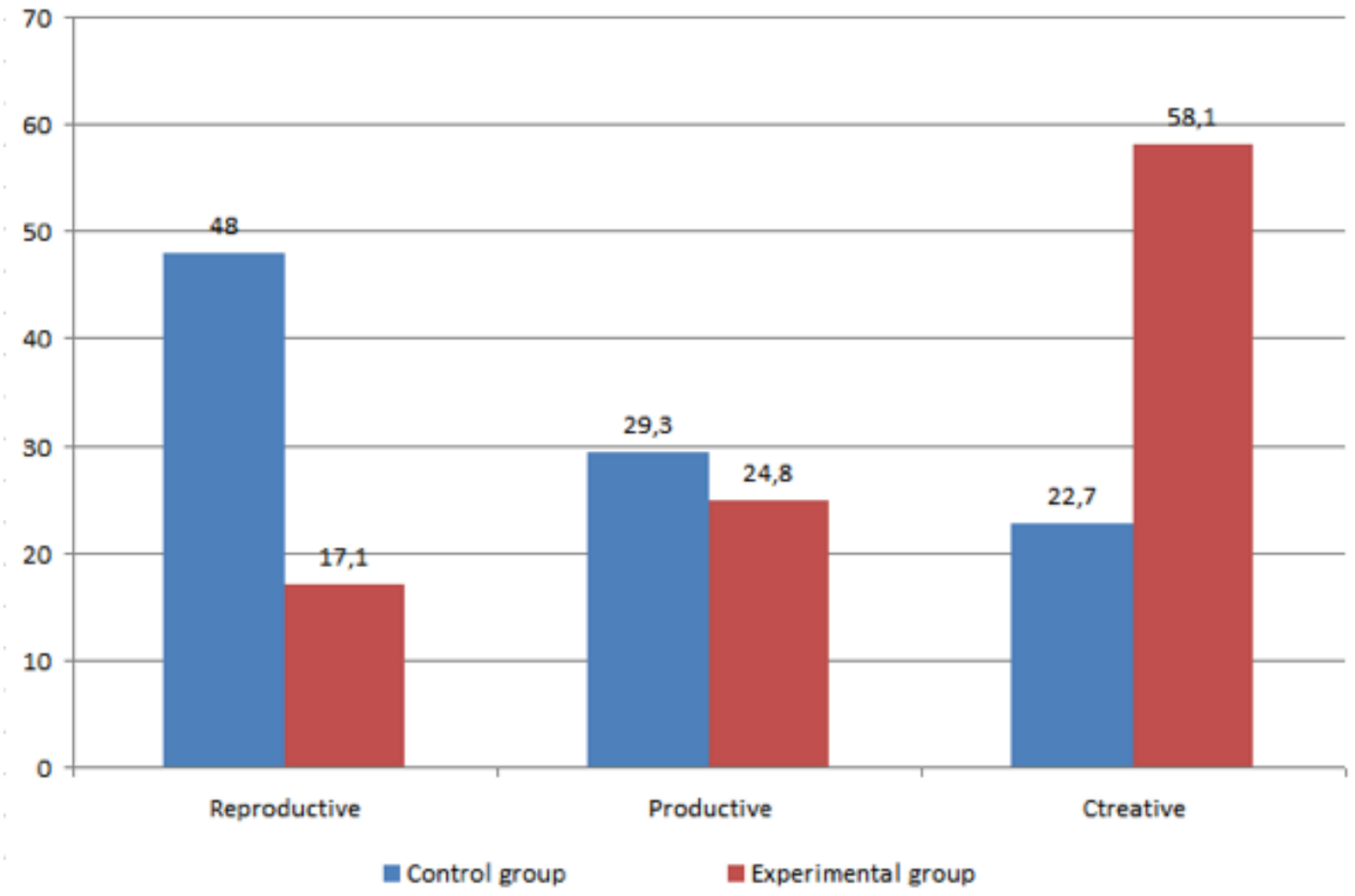
In control group studies were conducted through the means of a traditional lecture and seminar technique of carrying out studies at university. The lecture material and seminar classes were given to students and cadets; graphic tasks for the creative level of formation of spatial representation and perception, constructive and geometrical thinking were used. Independent work of students and cadets consisted in preparation to seminar classes, studying of educational literature and abstracts of lectures.

In experimental groups the classes were conducted by the described technology with the use of educational elements for forming of an approximate basis of activities during independent work of students.

Students and cadets of control and experimental groups were offered to perform the complex graphical work including graphical tasks of reproductive, productive and creative levels during the control phase. The GPA (Grade Point Average) was calculated for each

student by the results of accomplishment of the complex graphical work. Results of an experiment are given in the Figure 1.

Figure 1
The results of the experiment (original)



The experiment results show that in control group of 48% of students and cadets performed complex graphical work at the reproductive level, 29,3% - at the productive level and only 22,7% at the creative level, nearly a half of students and cadets couldn't rise above the reproductive level of formation of spatial representation and perception, constructive and geometrical thinking. In experimental group only 17,1% of students and cadets couldn't rise above reproductive level; the productive level of formation spatial representation and perception, constructive and geometrical thinking was reached by 24,8% of students and cadets; the creative level was reached by more than a half – 58,1% of students and cadets.

The assessment of reliability of results of pilot study was carried out by means of criterion of signs which allows to include up to 100 pairs of observations in the analysis and is based on calculation of number of the unidirectional results on their pair comparison. Students and cadets of control and experimental groups (only 90 couples) have been used as comparable pairs who have shown identical or close levels of geometrical and graphic preparation at the stating phase of the experiment. On the basis of statistical processing of the results of experimental work it is possible to state the reliability of results of the experiment within 95%. Therefore, it is possible to claim with the high level of reliability that the use of the developed modular technology reflected in a technique of carrying out studies and methodological support of the educational subjects "Descriptive Geometry and Computer Engineering Graphics" and "Descriptive Geometry and Engineering Graphics" allows to increase significantly the level of formation of spatial representation and perception, constructive and geometrical thinking among the students of the direction Vocational Education (branch "Mechanical Engineering and Materials Processing") at the Russian State Vocational Pedagogical University, and cadets, trainees on specialties "Fire Safety" and "Technosphere Safety" in the Ural Institute of State Firerfighting Servise of EMERCOM of Russia.

4. Discussion

The questions of the organization of an educational process in educational space of university were considered in works of E.M. Dorozhkin et al. (2016), E.M. Dorozhkin & E.Y. Shcherbina (2013), N.N. Telysheva (2014).

The features of training of bachelors of vocational education, structure of their preparation and the applied technologies and techniques were considered in the researches of E.V. Ketrish et al. (2016), E.M. Dorozhkin & E.F. Zeer (2014), S.A. Dneprov et al. (2016).

Separate aspects of the problem of graphic training of students of university and, in particular, questions of the organization of educational activity of students, were considered in the researches of A.D. Botvinnikov (1981), G.A. Vladimirskiy (1962), A.D. Gerasimova (1996), N.V. Kaygorodtseva (2014), N.E. Suflyaeva (2015), N.A. Salkov (2016), O.V. Yaroshevich & N.V. Zelenovskaya (2014).

The problem of formation and development of spatial perception of students was considered in works of G.A. Vladimirskiy (1962), A.D. Gerasimova (1996), P.Ya. Galperin (1998), N.F. Talyzina (1998).

Some principles of the implementation of modular technologies in training of students of university – the principles of variability, dynamism, flexibility, a modularity, etc., and also features of the organization of modular training of students of university on the basis of subject-modular approach were studied in the studies of P.A. Juceviciene (1989), V. Abasina & S. Yakob (2016), N.V. Borodina & N.E. Erganova (1994), K.J. Vazina (1991), M.A. Choshanov (1996).

The features of the implementation of the modular technologies of training based on system-activity approach the principles of the organization of study, the structure of the methodological support provided by the concept of "Modular Employable Skills" were considered and analyzed in the works of E. Crochet (1998), A.V. Krasnuik & T.V. Tatiana (2011), R.A. Amarin, O.O. Garibay & I. Batarseh (2013), V. Abasina & S. Yakob (2016).

The problem of quality assessment of university student training was covered in works of O.N. Tkacheva, M.V. Simonova & Y.V. Matveev (2016).

At the same time, it should be noted that the problem of formation of spatial representation and perception, and also constructive and geometrical thinking of students – future engineers studying on specialties "Fire Safety" and "Technosphere Safety" and also students – future bachelors of vocational education studying in the direction Vocational Education by means of application of the modular of organization of an educational process and methodological support – the educational elements created on the basis of the modular approach opened in the concept of modular training of "Modular Employable Skills" developed by the International Labour Organization in the previous researches wasn't comprehensively considered.

The complex description of the modular technology and the methodological support focused on formation of spatial representation and perception, and also constructive and geometrical thinking of future engineers and future bachelors of vocational education is presented in the present article; the pedagogical experiment, its results which can be extrapolated both to any other technical disciplines studied at university is described.

5. Conclusion

The results analysis of the experiment confirms high performance of use of the developed technology of forming of the approximate scheme of actions by means of use of educational elements within organized independent work of students when studying the module on the corresponding subject. It is possible to suppose that the use of the developed modular technology reflected in a technique of carrying out studies and methodological support of educational disciplines "Descriptive Geometry and Computer Engineering Graphics", and "Descriptive Geometry and Engineering Graphics" will significantly increase the level of formation of spatial representation and perception, constructive and geometrical thinking determining capabilities of students to the analysis and synthesis of spatial forms and relations on the basis of the graphical models of space which are almost realized in the form of drawings of specific spatial objects and dependences.

6. Recommendations

Extrapolating results of an experiment to other technical disciplines, it is possible to assume that the given technology will be effective also when studying disciplines which content requires the solution of both standard technical tasks, and development of productive and creative level during project and design work of an educational discipline. For instance, the following disciplines: Theoretical Mechanics, Theory of Mechanisms and Machines, Machine Elements, Strength of Materials, Materials Science, İndustry Equipment, etc.

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1. Chair of Engineering Technologies, Certification and Methods of Professional Training, Russian State Vocational Pedagogical University, Yekaterinburg, Russia. *Contact e-mail: mirdcom@rambler.ru*

2. Chair of Engineering Technologies, Certification and Methods of Professional Training, Russian State Vocational Pedagogical University, Yekaterinburg, Russia

3. Chair of Engineering Technologies, Certification and Methods of Professional Training, Russian State Vocational Pedagogical University, Yekaterinburg, Russia

4. Chair of Engineering Technologies, Certification and Methods of Professional Training, Russian State Vocational Pedagogical University, Yekaterinburg, Russia

5. Chair of Engineering Technologies, Certification and Methods of Professional Training, Russian State Vocational Pedagogical University, Yekaterinburg, Russia

6. Chair of Engineering Technologies, Certification and Methods of Professional Training, Russian State Vocational Pedagogical University, Yekaterinburg, Russia

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