The students' brainwork intensification via the computer visualization of study materials

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Abstract. The paper the approaches to the intensification of the students' brainwork by means of computer visualization of study material have been disclosed. In general, the content of students' brainwork has been presented as a type of activity providing the cognitive process, mastering the techniques and ways of thinking, developing the capabilities and abilities of the individual, the product of which is a certain form of information, as a result of the brainwork the outlook of the subject of work is enriched. It is shown the visualization is the process of presenting data in the form of an image with the aim of maximum ease of understanding; the giving process of visual form to any mental object. In the paper the content, techniques, methods and software for creating visualization tools for study material has exposed. The essence and computer tools for creating such types of visualization of educational material like mind maps, supporting notes and infographics have been illustrated; they have been concretized from the point of view of application in the course of studying the mathematical sciences. It is proved the use of visualization tools for study materials helps to increase the intensity and effectiveness of students' brainwork. Based on the results of an empirical study, it has been concluded the visualization of study materials contributes to the formation of students' key intellectual competencies and forming their brainwork culture.

Keywords: brainwork, intensification, visualization of study materials, computer visualization tools, mind map, infographics, supportive notes.

1 Introduction

The global informatization of society, transformation the Internet into a world repository of any information has substantially influenced the content of the educational process, methods and techniques of students' brainwork.

Thanks to the free access to the massif knowledge, there is no need for the traditional information accumulation because of its rapid aging and avalanching growth.

Therefore, the content of higher education should gradually change its direction, envisage measures to intensify the educational process, facilitate the formation of students stable processing skills and the use of constantly changing information in practice. Due to this fact, higher education should use special mechanisms that will reduce the emotional load on the central nervous system of both students and lecturers, and at the same time promote the intensification of students' brainwork. All these needs increasing the overall lecturers' teaching skills, as well as professionalization of education at the level of time's requirements.

It is the intensive teaching methods combining modern advances in scientific and technological progress in the form of automated systems and learning technologies that can be attributed to attempts to search in this direction. The most promising areas in this context are computerization and informatization [19], which provide increase the students' mental activities, and ultimately, the quality and continuity of higher education, mobility and competitiveness of graduates.

The *purpose* of this research is discovering and investigate the mechanisms of the students' brainwork intensification in the course of teaching mathematical sciences; studying the possibilities and check the effectiveness of the use of computer visualization tools in this process.

2 Materials and methods

In this paper we use methods of analysis and systematization of pedagogical and psychological literature, works of domestic authors, methodological materials in order to determine the conceptual and categorical apparatus of the research.

In general, the various aspects of the students' brainwork have been studied by Dmitrii N. Bogoiavlenskii [8], Boris P. Esipov [18], Petr Ia. Galperin [20], Valentyna M. Grineva [23], Yuliia S. Ibrahim [25], Nina V. Kuzmina [31], Nina F. Talyzina [59], Simon L. Soloveychik [56] and others. Scientists' investigations clarify the sense of culture and hygiene of brainwork, offer valuable ideas and recommendations on how to learn more quickly, how clearly comprehend and memorize of training material, how to work through and learn it, how to check the quality of mastered one. Separate attention scientists paired to those aspects of the researches revealing the psychophysiology of brainwork, to an analysis of the mechanisms of forming the mental activity's techniques, a rational organization and management of students' brainwork, and a reading culture, the methods of independent work with the educational book, etc. [43].

The intensification of brainwork is defined as the phenomenon of increasing its productivity in each unit of time. In view of this significant interest is the works of Iurii K. Babanskii [2], Vladimir P. Bespalko [5], Aleksei K. Gastev [21], Boris S. Gershunsky [22], Anatolii I. Kuzminskyi [32], Olena O. Lavrentieva [34], Oleksandr V. Malykhin [37], Leonid V. Zankov [66], and others. Scientists have characterized the following main directions of intensification and optimization of the educational process, such as: enhancing students' cognitive motivation, increasing the learning's content informative capacity, the use of active didactic methods and forms, scientific-

based management by the mastering knowledge process, development of skills and ability of brainwork with use the mnemotechnies, visualization, self-control, and self-efficacy techniques.

It should be notes that among the technologies of processing a large amount of data lately the technologies of visualization of educational material are actively used; they created on the basis of the works of Tony Buzen [10], Vasilii V. Davydov [11], German K. Selevko [52], Viktor F. Shatalov [55], Andrey A. Verbitsky [63] and others. Scientists' researches, including Alexei G. Baryshkin [3], Mark I. Bashmakov [4], Natalia V. Brovka [9], Hsinchun Chen [69], Viktor A. Dalinger [49], Thurston Domina [16], Nataliia A. Reznik [3], Joshua Saldana [16], Bin Zhu [69], and others, confirmed the fact that in the modern dynamic world where the computer-driven and smart-technologies are increasingly becoming a reality of our lives, the approaches to visualizing of educational content are must changing. Natalia M. Biloshapka [7], Steve Cunningham [70], Irina S. Dereza [12], Petro I. Dovbnia [17], Hennadiy M. Kravtsov [29], Pavlo P. Nechypurenko [44], Tatyana A. Oleinik [30], Valery M. Rakuta [50], Yurii S. Ramskyi [51], Olena V. Semenikhina [53], Andrii M. Striuk [57], Oleh O. Tsys [35], Oleg P. Zelenyak [67], Myroslav I. Zhaldak [68], Walter Zimmermann [70] have devoted their studies of the use of computer visualization tools in the educational process. Scientists justified the feasibility and necessity of using modern computer visualization tools, including computer mathematics systems and dynamic mathematics programs, as powerful tools to refine abstract mathematical models and processes.

This work will be analyzed the content and classification of computer visualization software offered by Jörg Müller, Daniel Polansky, Petr Novak, Christian Foltin and Dimitry Polivaev [36], XMind Ltd [65], Corel Corporation [41]. The results of empirical study of their effectiveness for intensification of students' brainwork in the teaching mathematical subjects' process will also be presented.

3 Theoretical background

3.1 The student's brainwork and leading approaches to its intensification

In our previous works [26], we have found that the concept of "brainwork" in most scientific studies is interpreted as a creative activity, which is accompanied by the tension of the sensory apparatus, the emotional sphere of the person and at the same time does not require however considerable physical effort [25, p. 16].

From a physiological viewpoint, brainwork requires less energy expenditure of the body compared to physical work. However, this fact does not mean its ease and simplicity. The main working body in the brainwork is the brain as such. Physiologists say that in intensive brainwork, its energy requirement increases to about 15-20% of its total volume in the human body. At mental load the oxygen is used as like 5 times as at maximum physical activity [26, p. 122]. The physiology state during of intensive brainwork is characterized by impaired balance of the processes of inhibition and excitation, deviates from the norm of the tone of the vessels of the heart and brain,

increases protein and carbohydrate metabolism, growths blood pressure and respiratory rate, etc. [43, p. 72].

That is, the interpretation of brainwork as an antithesis to physical one is very conventional. Moreover, these types of work make a mutual impact on each other. According to Boris P. Esipov [18] and Nina V. Kuzmina [31], the brainwork is characterized by strain of attention, memory, perception. In addition, a sedentary lifestyle and a monotonous posture cause stagnation in the leg muscles and, in the end, poor brain's oxygen supply [43].

As Simon L. Soloveychik is considered, the phenomenon of brainwork is the most complex type of human activity that goes unnoticed and inviolable [56]. Scientist states the brainwork is more difficult than any physical work, after that the person gets tired faster and recovers longer, besides the results of brainwork are not always visible and generally elusive. For example, when performing any physical work, anybody always sees changes in the labor object. However, somebody can work on solving a particular math problem for a long time, and eventually he/she can't find its solution. At the same time, representatives of psychological scientific thought (Dmitrii N. Bogoiavlenskii [8], Petr Ia. Galperin [20], Nina F. Talyzina [59], and others) argue the main difference between brainwork and any other type of work is its result. Product of brainwork is not only solution of a certain intellectual problem, but the enrichment of the outlook of the subject of work, change his/her attitude to reality [25, pp. 18–19].

Therefore, brainwork is a type of activity that provides the cognitive process, mastering the techniques and ways of thinking, developing the capabilities and abilities of the individual; the product of such work is a certain form of information, as a result of the brainwork the outlook of the subject of work is enriched.

When considering performance brainwork's indicators, takes into account its quality, productivity, as well as the optimal organization to achieve maximum results in a short time. It is not accidental in this conceptual chain the intensification of mental activity process has not last role.

The Latin term intensive (*intensio*) means tense, reinforced, doing increased productivity. Derived from it the term intensification (from French, Intensification – "the hard work") implies the achievement of the desired results in the work due to qualitative factors, it in the investigated by us context – due to the tension of the individual's mental capacity [32, p. 212]. In reference sources, intensification is defined as the process of increasing tensions, productivity, as the use of more and more efficient technologies, advanced methods of work, the achievements of science.

Nina F. Talyzina sees the intensification as a process decrease in the duration of training while increasing its quality and rising the amount of information assimilated [59, p. 59]. Similar definitions are typical of the works of Sergei I. Arkhangelskii [1], Natalia V. Kovalenko [27]. In the view of Sergei I. Arkhangelskii the essence of intensification of learning process lies simultaneously in the effectiveness of teaching, the effectiveness of studies and the effectiveness of study material [1].

The fact that in the process of extensive training (in contrast to intensive one) brain capacity is used only by 15-20% is indicated about necessity of the students' brainwork intensification. At the same time, intensive techniques require excessively high mental energy costs. Thus, the discrepancy between the requirements of scientific-and-

technological progress on improving the effectiveness of learning and lack of modern methods of information mastering put forward a problem of developing certain tools that ensure the efficiency and productivity of students' brainwork.

For the successful students' brainwork, and its intensification, it is advisable to strengthen the visual-figurative component of the study material. It is necessitating the use of knowledge imaging technologies, as well as providing compactness, expressiveness and dynamic presentation of the study material's content.

3.2 Visualization of study material as one of the ways of intensification of the students' brainwork

The term "visualization" (from Latin *visuals* – to perceive visual one) is defined as the process of presenting data in the form of an image for the maximum convenience of their understanding; it is visualizing any mental object [61]. At the same time, scientists are cautioned against such a simplistic concept of visualization if it comes to a didactical method or principle, and offer to separate visualization from a visibility.

As Andrey A. Verbitsky points out the process of visualization involves the collapsing of mental meanings into a visual image which in the future can be actualized in certain situations and serve as a support for mental and practical actions. For its part, a visibility is only a demonstration of those objects or phenomena, the presentation of the finished image, set from the outside. Thus, a visibility serves to support thought processes by performing an illustrative function, whereas the visualization implies active brainwork [63].

At the heart of the visualization method are important psychological processes. Viktor F. Shatalov proved that for better memorization and understanding, the study information must be formed into an image. Within the visualization process it is normalized, systematized and curtailed. In the following, the student who has processed study information via visualization will be able to reconstruct the ones content, to establish connections between facts or phenomena, what's more to give examples and to formulate conclusions [55].

In the educational process, such leading forms of visualization of study materials as supportive notes or schemas, intellect cards and infographics are widely used [7, p. 167].

Supportive Notes or schemas, by definition of Viktor F. Shatalov, are a system of reference signals that have a structural connection and a visual construction replacing the system of senses, concepts, and ideas as interdependent elements. The supportive note is built on the basis of a boundary one generalization, coding, "collapsing" of knowledge by means of conventional signs, symbols, diagrams, graphs, tables, and whatever [55].

Actually, not every laconic record can be the supportive notes. There are main theirs features, namely: 1) conciseness and clarity while the completeness of the information presentation are maintaining; 2) availability of keywords and nodal concepts; 3) the presence of structure both visual and logical; 4) simplicity and clarity of structure; 5) the existence of meaningful accents made with the help of different ways of design – colors, frames, fonts, graphics, schemes; 6) the use of abbreviations and conventional

symbols [60]. In Fig. 1 is shown the example of supportive note that demonstrate main ideas for designing such schemes.

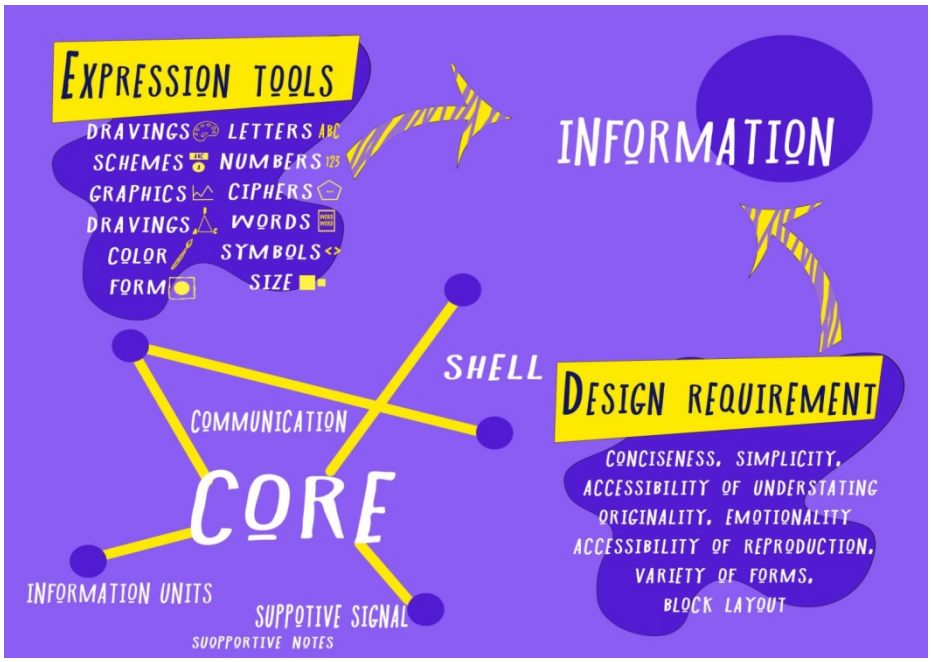

Fig. 1. It's example of supportive notes that devoted to main idea of such schemes (it prepared by authors with use [60])

Working with the support notes eliminates automatic rewriting of the study material. If, in normal note taking, a student either copy a text from a textbook or blackboard, as a rule without much thought in its meaning, then when student is drawing up a support notes this process involves pretreatment the information, isolating nodal elements and connections between them, creates anchor points for memorization [60]. At the same time, reprocessing the support notes, compared to reading the text, is considerably less time-consuming.

Mind Maps is a visualization of information in which step-by-step detailing of the art and graphic means of the studied concept or phenomenon is represented in a convenient format with the arbitrary addition of drawings and other auxiliary elements (arrows, lines, graphic symbols, etc.) [10]. With all their similarities to the supporting notes, mind maps are a dynamic means of visualization, that is, they are created in a certain period of time being required to process a certain part of the study material. The mind maps can help those whose personal and professional tasks suppose planning, organizing, and structuring.

Mind maps are a way of depicting the process of thinking through schematics usually in the form of a tree displaying ideas, concepts, keywords related to branches that extend from the central object of the map. Sometimes other translations of the term are

used: “intelligent card”, “associative cards”, “memory cards”, “mental cards”, “smart cards”, “maps of consciousness”, “maps of mind”, “maps of representations”, “diagrams of communication”, etc. [45].

The advantage of using mind maps is follow. Firstly, they allow capturing everything with one look, since these schematic diagrams show the most important in associative comparisons and interactions. Secondly, mind maps are an example of a rational correlation of verbal, symbolic information and visual images. These are contributes to the development of students’ visual thinking, which in turn organizes images, systematize, structures and makes them holistic. These things far and away make students’ brainwork more purposeful, concentrated, and resulting.

Mind maps as an effective visualization tool was re-invented by well-known expert in intellect field Tony Buzen. The scientist paid attention that human thinking is nonlinear but has a kind of branch structure. Here each concept is connected with other concepts, in turn; these other concepts are connected with third ones and so on. Therefore, working with mind maps significantly intensifies the development of new concepts, ways of thinking and the general students’ brainwork. Throughout a such activity, students study to express thoughts briefly and clearly, to encode information, to structure it, to restore causation, to do conclusions [10] (see Fig. 2).

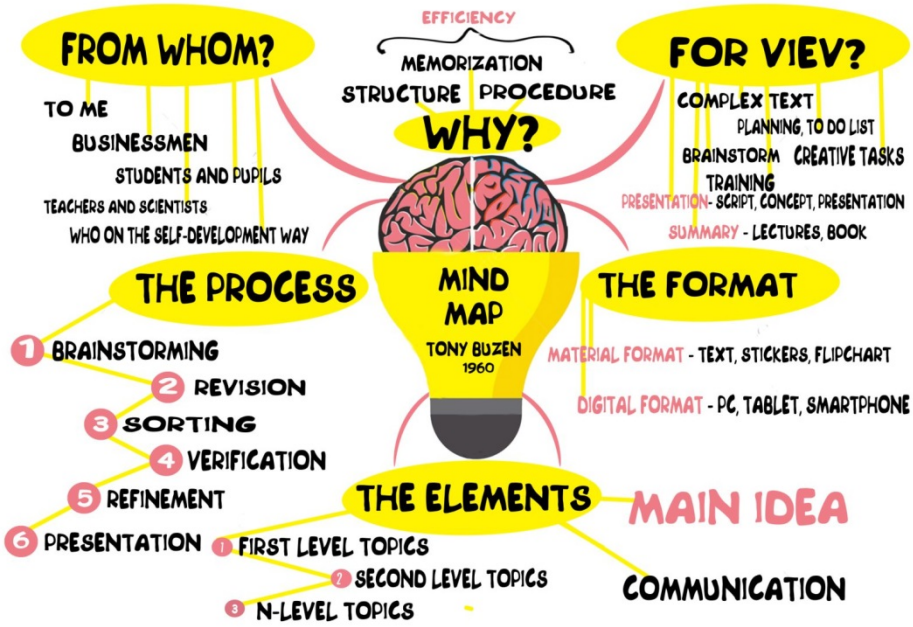

Fig. 2. The Mind Maps by Tony Buzen concept (it prepared by authors on the analogy of [41])

Infographics (one combines the terms “information” and “graphics”) are representation of interconnections between data sets (concepts, phenomena, etc.) in a convenient visual form by art and graphical means. In contrast an image, infographic conveys

meaning, content, or data with the help of drawing but not the text [13]. A sign of infographic is the preservation of meaning in the image, from which mentally or technically the text explanations are removed [33].

In the heart of infographic technology is the fact that images makes the data more attractive to perceive by whomever, and increase his/her memory efficiency. It is well known that to 90% of information is perceived by a person visually, an additionally human brain processes visual information much faster than textual. In line with this regularity it is advisable to use infographics when you need to present a large amount of information in a compact and logical way [69].

The tutorials with infographics activates the process of perception and understanding of information, increase students' ability to think critically. The principal advantage of infographic images is providing information saturation and clarity of study materials, appeal to the existing user experience. Accordingly, information graphics is an intermediary in the path of choosing the trajectory of perception and information processing by student [64, p. 200] and so it is a significant tool in students' brainwork organizing. In general, Iryna B. Chebotarova [14] based by way of presentation and type of information proposes to consider 5 types of infographics (Fig. 3 shows it).

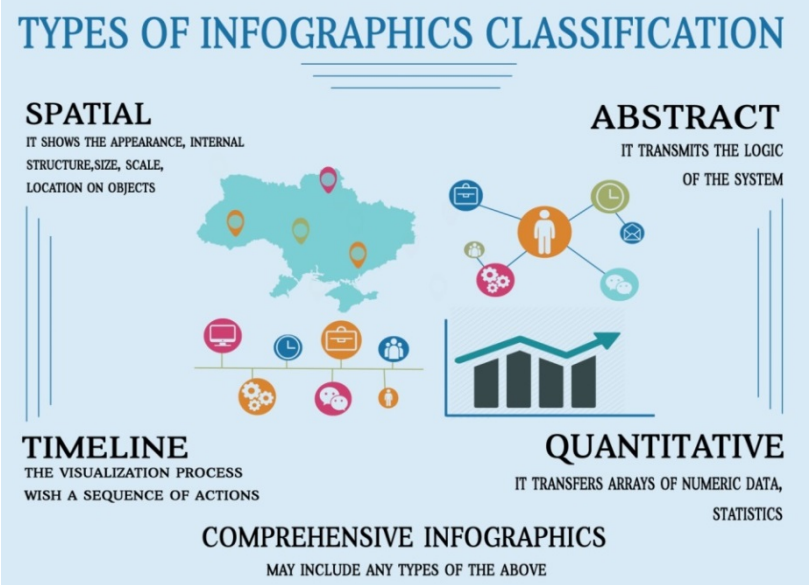

Fig. 3. Types of infographics by way of presentation and type of information (it prepared by authors on the analogy of [14])

These are such as:

- The spatial infographic showing the appearance, internal structure, size, scale, location of objects, path from one to another.
- The timeline infographic illustrating either chronology or a sequence of actions.

- The abstract infographic transmitting the system's logic (hierarchy, block diagram, diagram of relations, mind maps, etc.).
- The quantitative infographic reproducing arrays of numeric data or statistics.
- The comprehensive infographics that can include any above-listed types [14, p. 10-11].

These visualization tools are widely applied in textbooks and all kinds of reference books containing summary information and commonly used knowledge.

In view of the above, infographics have a high potential that can be used as a useful tool to intensify the students' brainwork. Infographic objects stimulate the simultaneous operation of the left and right hemispheres of students' brains complementing the imagery of an abstract model of the object, making the perception more comprehensive, the thinking – deeper, the learning – more interest and intense [58].

The review of major visualization tools (mind maps, infographics, support notes) made determines their essential importance for the fruitful students' brainwork thanks to the physiological and psychological mechanisms of its intensification that realized in them.

4 Techniques of computer visualization the study materials

4.1 An overview of leading ways to visualization

Different tools can be involved in the visualization including computer and non-computer ones. The first way is based on use widely available computer software, which developers provide opportunities for visual representation on the screen or in the printed form of abstract objects, processes, their models, and whatever. In spite of all the attractiveness of prepared computer visualizations, self-created diagrams, maps and infographics have considerable advantages, in particular: it is the quickness and the possibility to reproduce at any moment and wherever, better memorization and more painstaking students' thinking activity [70]. Consider the methods of their creation and approaches to use in the mathematics learning process.

The technique of "supportive notes" was proposed by Viktor F. Shatalov. He developed and put into practice the technology of study intensification that showing the huge, not yet discovered reserves of the traditional class-and-lesson system [55]. We mean the following aspects. The "support" is an indicative basis of actions, a way of external organization of the student's internal mental activity. The "support signal" is an associative symbol (sign, word, diagram, pattern, etc.) replacing a certain semantic meaning. In turn, the "supportive note" is a system of support signals in the form of a short conditional synopsis. In it all basic concepts and methods are introduced and explained, the illustrative examples, control questions for self-testing, and the solutions of typical problems are given. The material is presented in the same sequence like in the lectures but without evidence. Only definitions, formulations and explanations of the material, its interpretation, as well as drawings, conclusions, rules are given. The secondary issues are generally being omitted here.

Pedagogical experience usually uses teacher-pre-prepared supportive note, for example, to prove theorems, explain complex concepts, interrelations between mathematical concepts, memorize patterns, and so on. The lecturer presents the students with a supportive note, explains its structure. During the course of the explanation students redraw the note, or, using a ready one, make explanations, notes or markings in it. While working out this material at home, the student as if reproduces it according to the supportive note's logical structure. Individual students may be asked to write supportive note independently [60].

The supportive notes on mathematics can be made in the form of frames, logical circuits, part-whole schemes, radial circuits, clusters, Euler-Venn diagrams, Pyramid-type circuits, tree structures, and whatever [70].

A mind map is a way to visualize the process of thinking by creating non-linear schemes. This is a way of fixation the process of thinking, which most similar to how thoughts and ideas are being born and developed in our brain.

The map has a so-called radial structure, remotely resembling a tree, or a spider, or an octopus, or whatever that has a center and branches. The procedure for working on the creation of mind maps implies the following sequence of actions. In the center of the sheet the main image (generic concept, phenomenon, and problem) is being drawn. From it the key branches of the first level to the images illustrating the specific concepts that associated with central image is being led. It is recommended the branches reflect top ideas revealing these associative links. Further the branches of the first level will be digress from the branches of the second level, and so on until the whole issue is clearly worked out or the task is not addressed. Blocks should not be placed tight enough, as they can be supplemented, become surrounded by new connections, branches, data, examples, etc. [10].

The geometric data (families of triangles and quadrilaterals and their properties, shapes in space and plane) are conveniently to represent on mind maps. Algebraic mind maps are also popular. They show methods of solving logarithmic, trigonometric, quadratic, etc. equations, actions with numbers, and rule of differential and integral calculus.

The infographic is one of the forms of graphic and communication design of study material intended to present information quickly and clearly [62]. Not only infographics organize large volumes of information, but it also more clearly shows the links between objects and facts in time and space, as well as demonstrate trends. This visualization tool is widely used in textbooks and all kinds of reference books for math containing summary formulas and commonly used mathematical transformations, heuristics, and other interesting things.

As researchers consider there are two approaches to infographic design [33]. One is the explorative way elaborated by Edward Tafty [15]. This approach is characterized by a minimalist format. Here everything irrelevant isn't being indicated, and the information is being conveyed as accurately as possible. Another direction is the storyline or narrative approach based by Nigel Holmes, who created the explanation graphics [24]. The specified direction of infographic is characterized by attractive images, expressive design, illustrative [46]. In our opinion it is advisable to use a

harmonious combination of both approaches for intensification the students' training as well as their brainwork.

Evidently, it's not easy to create quality infographics. So as to work up a functional infographic, one has to go through many variants of their presentation, has basic knowledge about tools of information's performance, and a high level of understanding of this process. Infographic is atypical visualization. It has own peculiarities and differences. As researches emphasize the infographic is an individual manual work for a particular dataset [46].

The creation and use of paper non-computer visualization tools are quite painstaking and ungrateful work. It's no wonder that in nowadays the computer visualization is haven a number precedence over non-computer one and being use more and more in educational process.

Natalia M. Biloshapka interprets the concept of "computer visualization" as an app, in which it's possible to visually present on the computer screen abstract mathematical objects and processes, their models in a compact form (if necessary in various viewpoint), or vice versa, in detail – with the possibility of demonstrating the internal interconnections between the components that are usually hidden in the real world [6].

When all's said and done the impact of computer visualization on the intensification of students' brainwork should be resulted and generalized.

We suppose the visualization of study materials is:

- contributes to the better assimilation its scientific structure by students;
- enables to independently select the pace of mastering a new study material;
- opens the possibility of manipulation of information for the purpose the efficiency of the organization of independent work and repetition of previously studied material;
- presented the dynamic information activates the simultaneous operation of different types of memory that in turn increases the degree of the information perception, and in the end enlarges the efficiency of the student's brainwork.

The aforementioned features allow students to integrate both traditional statistical information and dynamic knowledge during the brainwork.

4.2 A survey of computer visualization software

Computer visualization tools designed to support the teaching of mathematical subjects are divided into two types: general purpose software and specific mathematical one [54].

General purpose software tools provide a presentation of study material in a compact, logical, holistic form that makes it possible to intensify learning, effective of learning activities and, in the end of the day, to shape the culture of students' brainwork.

In the heart of general purpose tools is computer graphics allowing to create, edit, and convert graphics for any goals. Appropriate software has been developed for working with graphic information including viewers, graphic editors, photo editors, as well as specific tools – a graphic tablet, a digitizer.

There are various graphic editors and packages (Adobe Photoshop, CorelDraw, 3D Studio MAX, AutoCad and others), multimedia product development and demonstration programs, text editors, and desktop publishing apps, etc. They allow adding arsenal of visualization tools of educational information. In particular, these are enable to use elementary and complex geometric shapes; to correct and to draw fairly complex lines of different thickness and texture, to adjust points of various sizes, to do fill, repaint, exchange colors and their brightness and transparency, to work with fonts and graphic templates, to experiment with scaling, proofs and layout of elements, with shadows and whatever [70]. However, successful work with such software requires lecturers and students specific art and graphic abilities and skills. The Figs. 1-4 are shown the results of the creation of such tools for visualization of study materials. So, further it will be look at computer visualization tools that can be mastered by any average person at the competence's level.

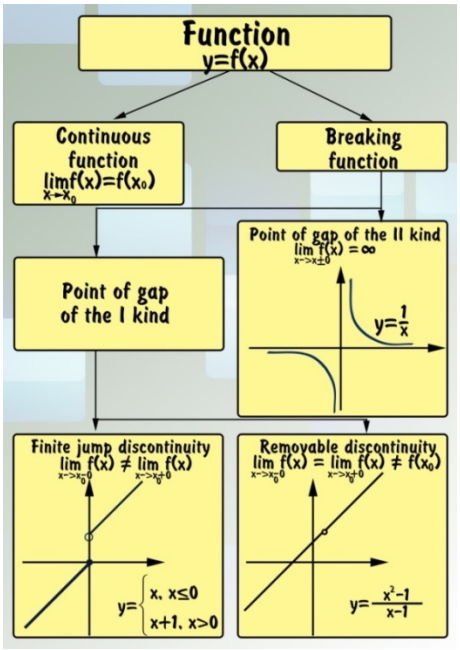

Fig. 4. The supportive notes prepared by one of authors in Adobe Photoshop environment

Researchers (for example, Olena V. Semenikhina and Natalia M. Biloshapka) include to general purpose software set following: 1) office software packages with Smart-Art objects; 2) apps for realization of mind mapping technology; 3) apps for creating infographics; 4) apps for creating a scribing presentation [53].

Smart-Art objects are a new type of graphic objects allowing the data in a text document are being structured or presented their in schematics. It makes possible to do the mastering of a new study material visual and step-by-step (by algorithmic way).

Mindmapping is a technology enabling to systematize and synthesize the knowledge gained through the formation of mind maps [45].

Scribing – sketches or drawings – the latest presentation technique, in which speech is illustrated with drawings. It creates a "parallel passage effect". In result we hear and see the same thing, but the graphic is fixed only the key points of audio series. In this sense, scribing can be put on a par with infographics. Computer scribing presentation can be made with the PowToon service and the VideoScribe software, as well as modern smart-systems. It should emphasized the scribing presentation also requires mastering a certain art and graphic skills [38].

Therefore, we would like analyze in more detail the software environments for making the computer visualization of study material. Among the applications that allow the creation of mind maps and infographics there are the standalone applications – XMind, FreeMind, Mindjet MindManager 2019, as well as the cloud services – MindMup 2 For Google Drive, Bubbl.us, Mindomo Basic, and a lot of others.

XMind is a software tool to make visualization means that is installed on different operating systems. The program contains a large set of pre-made templates that can edit and create author's visual products. The software toolkit lets to do export documents to Microsoft Word, Microsoft PowerPoint, PDF-editors, to choose image format (bmp, jpg, gif, and png). The program has several versions: free proposal with cut-down features and paid one with advanced functionality [65].

The main disadvantage of using the XMind free version is the inability to add images, mathematical formulas, videos, audio and more things to the illustration. In a word, such visualization tool can contain only text and character information.

Mind maps created in the XMind free version can be used in higher mathematics practical classes at the stage of actualization students' supporting knowledge. For example, during students study the content of topic "Straight line on the plane" the lecturer at the beginning of the practical training indicates by means of mind map (see Fig. 5) names of the basic types of the equations and main simplest tasks about straight lines on the plane. From one's part students must supplement each name with the corresponding mathematical description that they got to know within a lecture.

A such form of consolidated of study material contributes to the intensification of students' brainwork, because the completed mind maps can be used repeated, after addition and processing. It causes the model of study information to be fixed in the students' imagination and fasten into long-term memory.

FreeMind is a free mind maps builder running on any Java-enabled platform. The program has advanced export capabilities in png, jpeg, xml, html, xhtml, OpenDocument Text formats; plugin for export to svg and pdf. Exporting xhtml allows to create a mind map with links to external sources. In fact, the program has all the tools and features that need to make high-quality vizualization tools [36].

Consider an example of a mind map created in the FreeMind software environment. In course of the presentation study material "The derivative and its application" at the lecture session the main topic's directions could be advisable determined via the structural and logical scheme (it shown on Fig. 6). Further this mind map can serve for a guide mark at the stage of generalization and systematization of students' knowledge for establish gaps in the studied material.

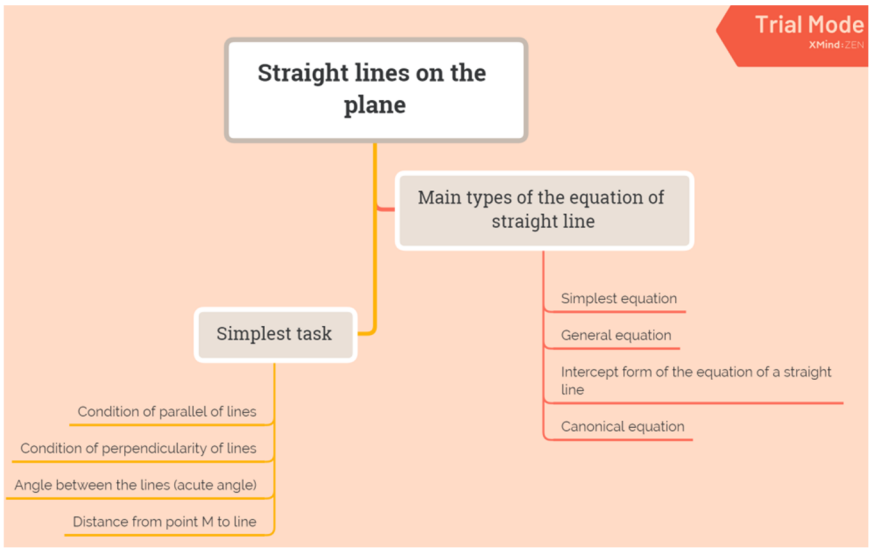

Fig. 5. Mind map created by one of authors into XMind

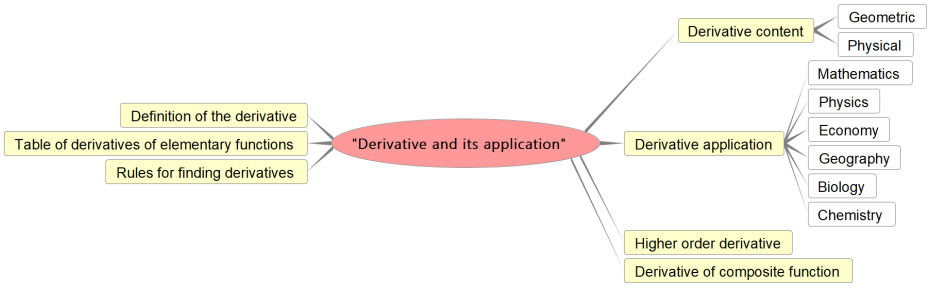

Fig. 6. The structural and logical scheme "The derivative and its application" created into the FreeMind software environment

Mindjet MindManager 2019 is commercial software for managing visualization tools. This app offers the different ways to create mind maps. It can be a blank map to which one adds all the necessary data, or a template, or a part of an existing map as the basis for a new one. MindManager cards can be exported to Microsoft Word, PowerPoint, Visio, and Project, saved both web pages and PDF documents. It should be noted the capabilities of MindManager in the stylistic design of different types of mind maps are quite wide [41].

Let's consider an example of using MindManager cards in course of studying the topic "The Polyhedron". The structure of mind map (see Fig. 7) is reflecting the classification of polyhedron based on the properties polygons that are the faces of polyhedron. Apparently, such maps help to develop the students' abilities to generalize and classify objects by generic, species and other characteristics; as well as they contribute to the streamlining of knowledge and a deeper understanding of the semantic

structure of the topic. To general advantages of the mind map “Polyhedron” should be add possibility to create a set of tasks with incomplete data. It can be cards with polyhedron names but without corresponding images, and vice versa; as well as cards with images but without formulas, and on the contrary.

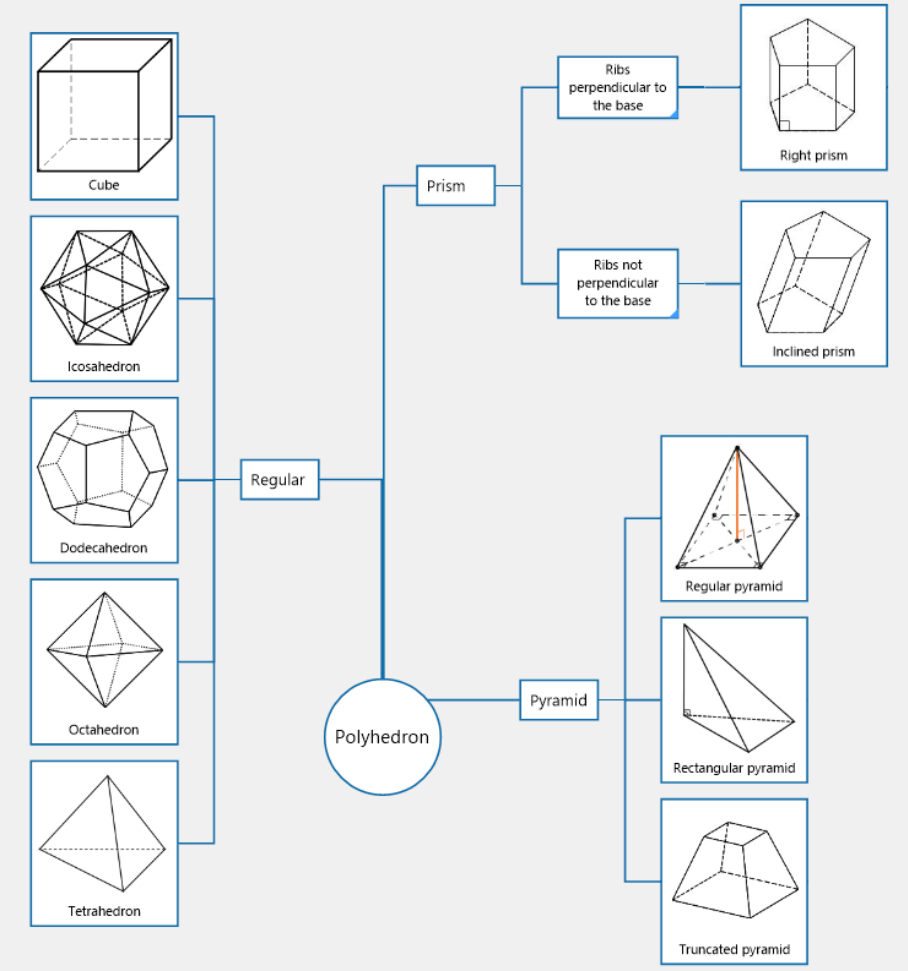

Fig. 7. The mind map for studying the topic “The Polyhedron” prepared in MindManager environment by one of authors

Let’s consider an example of using MindManager cards in course studying the topic “Matrix” (see Fig. 8). Such mind map can be used as basis to task solution on highlight key concepts of the topic. What’s more it can also be used as a basis for hands-on exercises on to supplement the mind map with missing information, in particular: to add a images of the matrices types, the scheme of actions over matrices, formulas of properties of actions with matrices, schemes and formulas for calculating the

determinant of the matrix, and whatever.

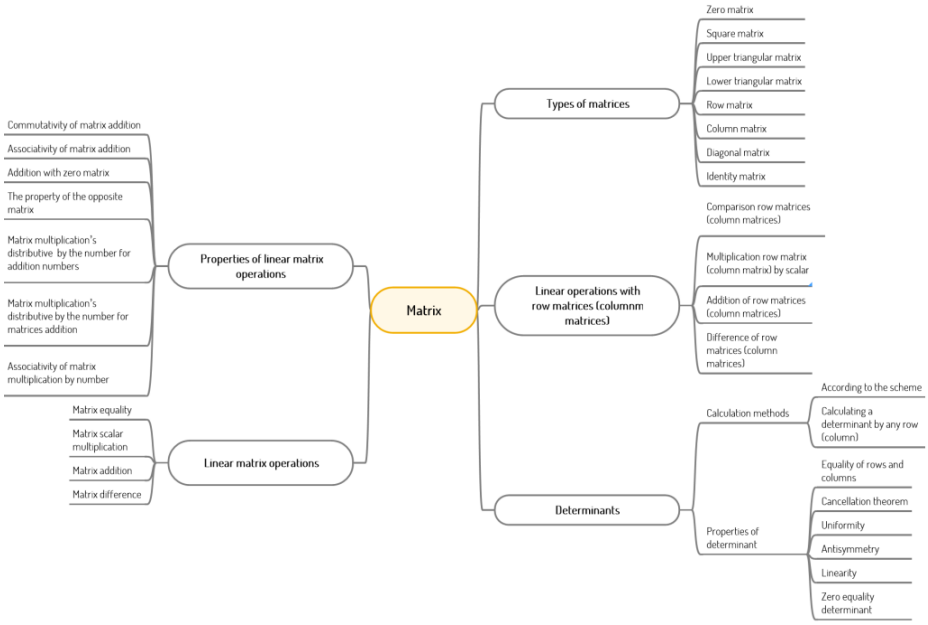

Fig. 8. Mind map "Matrix" prepared in MindManager environment

Students are able to do it, either in MindManager app or in any other graphic editor or by hand on the printed maps.

MindMup 2 For Google Drive is a local app that integrates with Google Drive users. Mind map created in this online service saves automatically. However, the possibility to export mind maps for the free version is limited only objects to 100kb in size. In addition, Google Drive mind maps can only be stored for 6 months. A Custom Gold package allows creating mind maps already to 100MB and store them on Google Drive. The Corporate Gold package removes any restrictions for users [42].

Bubbl.us is a relatively free local software environment for creating simple mind maps and exporting them in image format. The program can change the color and font of the text, the color of the nodes, and the general color scheme of the intellect card [40].

Thus, despite the various functional capabilities, the apps that were discussed above are built on the basis of a united principle for creating visualization tools of study material for any educational subjects.

4.3 The special mathematical visualization software

Special mathematical visualization software includes programs of dynamic mathematics. They provide dynamic operation of various mathematical objects with

the possibility of interactive obtaining of information about their properties [6]. These programs allow doing animation and manipulation with mathematics' objects. One such software environment is GeoGebra [28].

GeoGebra is a free math program including tables, graphs, statistics and arithmetic. It benefits embrace a friendly interface and powerful features that allow creating interactive study material [48].

Major resources of this system cover to: calculation of mathematical functions, creation of Java applets for insertion into Web pages, integration with the system of distance learning courses [17]. The GeoGebra can also use as a virtual lab for developing interactive models of mathematical objects, as a scribing tool, as an environment for creating illustrative material and developing interactive exercises.

Consider the functionality of the GeoGebra in course of study of the unit "Derivatives and its application". As our experience is shown the most effective and expedient is the use of a dynamic mathematics system on such stages of studying a topic, namely:

- finding a derivative of function (students can perform a self-test by comparing their results with the result of a program; it contributes to saving time);
- finding the equation of tangent line to the graph of the function (students construct the graph of function and find equation of tangent line analytically, and then on the type of completed construction they determine whether the desired line is tangent one);
- using the derivative of function to solve applied tasks (exploring the models into GeoGebra);
- studying the monotonicity and extrema, convexity and inflection points of the function (student checks the correctness of conclusions by plotting the graph of a derivative function by means of GeoGebra) [12].

The tasks are being carried out into the GeoGebra software environment aren't just illustrations. While the working the app saves an algorithm with all the steps and raw data that can be edited as needed. Any changes to the algorithm are immediately reflected in the graph. This significantly reduces the time spent on correcting errors, since it does not require repeated execution of the task from the first step [67].

One advantage of using the GeoGebra system is the possibility to manipulate of mathematical objects that allows keeping track the changes in their geometric interpretation. In Fig. 9 the intermediate and final results of modeling into the GeoGebra environment while studying the topic "Sum and Difference of Complex Numbers" is shown. In this model the complex numbers are given in algebraic form then the results of actions on them in graphical form are represented. To change the parameter values into the environment there are sliders located on the top right of the screen.

The solving higher mathematics tasks in the GeoGebra software environment, students should not be given a readymade dynamic model or a readymade demonstration algorithm. Initial skills in working with GeoGebra should be given, and then offer to students to create of graphic images of the studying subject.

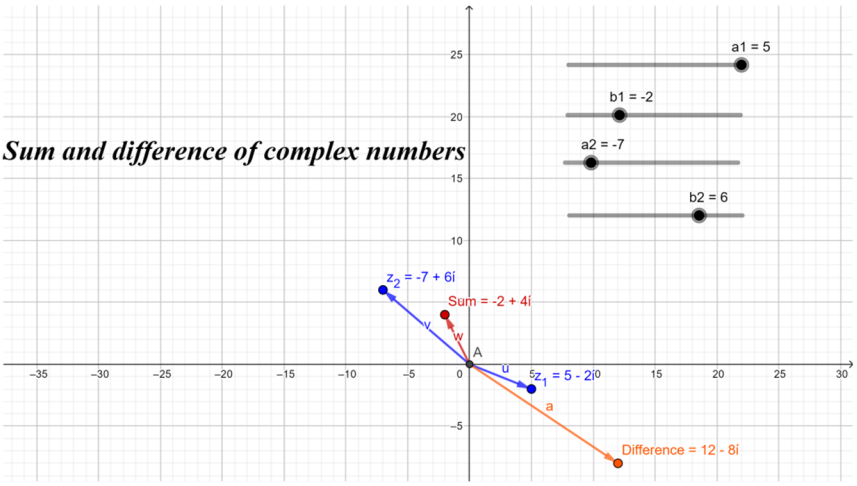

Fig. 9. The results of work into the GeoGebra environment

It can be concluding that the use of the GeoGebra mathematical program allows submit calculations in an easy-to-read form, to combine calculations and construction on united worksheet, thus increasing the studying productivity. It taken into account that getting outcome during changing the value of the parameters does not require additional calculations, any notes or create consistent conclusions. The involvement of the dynamic GeoGebra program leads to an intensification of the students' brainwork as the process takes place against the background of instant visualization [47].

The solving higher mathematics tasks in the GeoGebra software environment, students should not be given a readymade dynamic model or a readymade demonstration algorithm. Initial skills in working with GeoGebra should be given, and then offer to students to create of graphic images of the studying subject. This kind of activity contributes to the students' brainwork intensification and the deeper learning of the mathematic.

4.4 The investigation of effectiveness of usage the computer visualization tools as a means of intensification the students' brainwork

In order to test the effectiveness of the study material visualization for the purpose of intensifying the students' brainwork the experimental work has been organized. The investigation has been conducted on the Technology and Preschool Teacher Faculty of Kryvyi Rih State Pedagogical University throughout 2017-2018 years and covered 213 number of participated.

During the experimental work it has been developed and tested: a set of mind map, infographics, supportive notes to the main units of the course "Higher Mathematics"; methods of working with them both in the classroom and in the process of students' independent study activity; a system of training tasks based on computer visualization tools including mining and scribing presentation. Some aspects of the above are

disclosed in the previous text of this paper.

The intensification of students' brainwork in the teaching of mathematical sciences was ensured by the involvement of certain computer visualization tools to solve competently oriented tasks, among them: creating of visual models to basic mathematical concepts, laws and rules; working with the prepared visualization tools manually and with use visualization software; compiling a task system via the computer and ICT tools.

The effectiveness of the developed methodology the students' brainwork intensification via the computer visualization of study materials has been evaluated by such indicators as: the degree of mastering the main concepts of the topic (diagnostic control work); interest in the subject and in the study of visualization tools (questionnaires and interviews with students and lecturers); time required for learning mathematical concepts and laws (chronocards methods).

It has been fixated the students highly appreciated the opportunity not only to reduce the time for the preparation to the classes but also to acquire the professional skills of the organization of brainwork by means of computer visualization tools. 63,2% of the students give preference to use general-purpose tools of computer visualization to develop their professional careers. At the same time 81,6% of students are inclined to apply the special mathematical visualization software. 51% perceive would like be able to obtain specialist knowledge in the management of the other people's brainwork (students, subordinates, project team members and whoever).

By virtue of the experiment results an increase in the degree and completeness of mastering knowledge in mathematical sciences by students has been noted (see Fig. 10).

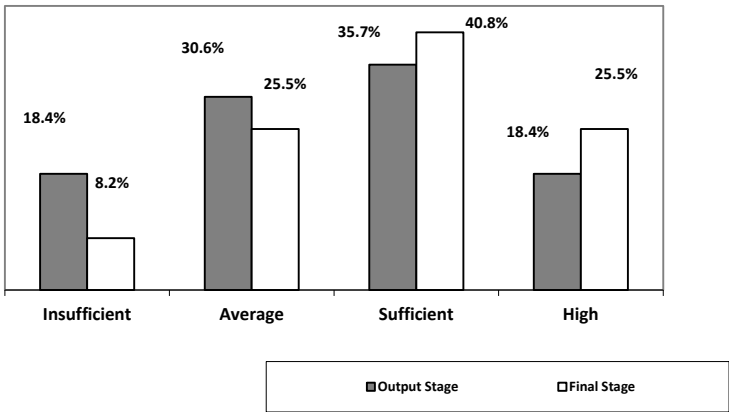

Fig. 10. Dynamics of the levels of students' knowledge mastering in line with experimental work's results

In order to find out the degree of intensification the students' brainwork a chronocards method has been applied. They have been used to record the time spent on by students to solve learning tasks via computer visualization tools. The degree of intensification the students' brainwork has been estimated by the coefficient of intensification. This is

a correlation between time that students spend on to execute the tasks with use the computer visualization tools and non-computer ones (to take more details see Table 1).

Table 1. The coefficient of effectiveness the use of computer visualization tools in the process of higher mathematics study

Types of tasks	The coefficient	
	Output Stage	Final Stage
Definition of mathematical concepts	1,1	0,8
Terminological work	1,2	0,5
Graphic, computational and practical tasks	1,0	0,7
Educational projects	0,8	0,5
Mastering the mathematical concepts and laws	0,8	0,5
Concretization of knowledge	1,2	0,8
Systematization of knowledge	1,3	0,7
Search for interrelation between mathematical concepts	1,4	0,6
Building models of mathematical phenomena	0,9	0,5
Independent study work	1,1	0,6
Creation of schemes, technological cards, consolidated tables, construction of charts and diagrams	1,2	0,7
Mindmapping	1,3	0,7
Self-monitoring, test-control	1,0	0,6

It should be noted that the obtained results confirmed the high efficiency of computer visualization tools to intensify the students' brainwork in the process studying of higher mathematics. Meanwhile, it has been confirmed the introduction of computer visualization tools should be integrated one and provides for a variety of visualization forms, the methods of their creation and processing, and, last but not least, a necessity development of a special series of tasks which directed on working with them.

5 Conclusion

The analysis of the research results on the intensification of students' brainwork via the computer visualization tools has made it possible to draw the following conclusions:

1. The brainwork is a leading aspect of students' study and cognitive activity. This phenomenon implies mastering the techniques and ways of thinking, developing the individual's capabilities and abilities. Therefore, the issue of improving the efficiency of students' brainwork in the terms of the introduction of student-centered learning is an important pedagogical problem.
2. The intensification is defined as the process of increasing tensions, productivity, as the use of more and more efficient technologies, advanced methods of work, the achievements of science. The intensification of learning process lies simultaneously in the effectiveness of teaching, the effectiveness of studies and the effectiveness of study material. The computer visualization tools are such mechanisms. Thanks they are being used the speed of perception of information flows by means of visual

images increases significantly, and as a consequence the student's brainwork becomes more intense and productive.

3. The term "visualization" is defined as the process of presenting data in the form of an image for the maximum convenience of their understanding; it is visualizing any mental object. This phenomenon does not boil down to illustrating and demonstrating the study materials. In the educational process, such leading forms of visualization of study materials as supportive notes or schemas, intellect cards, mind maps and infographics are widely used. Different tools are involved in the visualization including computer and non-computer ones.
4. Computer visualization is thought like an app, in which it is possible to visually present on the computer screen abstract mathematical objects and processes, their models in a compact form or vice versa, in detail. There is the computer visualization tools designed to support the teaching of mathematical sciences. They are being divided into two types: the general purpose software and specific mathematical one. The intensification of students' brainwork via computer visualization tools requires the development of a special methodology to use it in the Higher Mathematics course, and a system of training tasks based on so-called "minding" and "scribing".
5. An empirical research confirmed the effectiveness of using the computer visualization of study materials to intensify the students' brainwork in the teaching mathematical sciences' process. It was recorded that students praised the opportunity not only to reduce the time for preparing for classes, but also to acquire professional skills in organizing brainwork by means of computer visualization. Last, but not least, an increase in the degree and completeness of students' assimilation of knowledge in mathematical sciences is noted.

The presented study does not exhaust the problem of the students' brainwork intensification. On authors opinion it should expediently develop the content of special courses aimed at forming the culture of students' brainwork both with the help of modern information technologies and traditional non-computer ones.

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