Structural and logical circuits in learning activities under conditions of education digitalization

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Abstract. The digitalization of the educational system is more aimed at developing an independent, responsible and creative person. The more knowledge a student receives independently and actively engaged in self-education, the more he needs help, both practical and definite. Digitalization of the educational process requires a special approach to its development, redefining the role of the professor, searching for new possibilities of interaction between all participants, adaptation of existing or development of new methods and means of knowledge transfer and their control. One of the didactic methods of activating the cognitive abilities of students, which include thinking, memorizing, perceiving, imagining and presenting are structural and logical schemes. Their application in educational activities solves several tasks: the meaningful acquisition of new knowledge and increase the intellectual and creative potential of students, the study and use of services, programs or mobile applications to structure information and transform it into clear logical schemes for memory and playback. This article discusses the peculiarities of applying structural and logical schemes at different stages of the educational process in the conditions of education digitalization.

1. Introduction
Each time it takes less time from one stage of society development to another; each subsequent stage of society development is shorter than the previous one (the Law of Acceleration of Development). At the same time the amount of information increases and for its processing, storage and transfer special formats (digital codes) and digital technical means are involved. Digital and information technologies are used for analysis of production and resources, their development, information exchange, staff training and professional development. The nascent system of economic, social and cultural relations based on the use of digital communication technologies is a relationship of a new format, in which along with the real physical world there is a virtual reality. The main changes in the educational system are related to its digitalization, which leads to a change in the organization of the educational process. For effective teaching, methodical and didactic maintenance of digitalization of an education system the following tools are needed: for creation of educational materials, for effective delivery of the educational content helping pupils to master independently a new material, to control of knowledge of students. At the same time, educational process is the directed and organized interaction of the professor (subject) and the student (object) its efficiency depends also on their personal qualities in the conditions of education digitalization.

A modern student is a "digital person" who already exists in a digital environment, for whom gadgets, tablets, smartphones, computers, sites, IP-protocols, web services, interfaces are simple and clear day-
to-day things; for whom the main source of information, entertainment and often already the field of professional activity is the Internet. But in this case a student must be motivated, know what he wants to get from education, be disciplined, capable of self-organization, self-education, be able to adequately assess themselves, to differentiate resources and information. For Universities, especially technical universities, the provision of educational process in a number of disciplines in the conditions of digitalization presents a considerable problem: laboratories, layouts, models of industrial equipment are not so easy to make virtual. In addition, it is not possible to undergo online an internship and ensure proper control and accounting for remote studying. The way out of this situation can be the use of mixed learning, which allows combining online and offline formats (distance learning is rather a forced option) [1]. The professor acts as a guide, counselor, and organizer of learning and cognitive activities.

2. Discussion and results
A variety of didactic methods, techniques, and tools can be used to absorb and assimilate learning materials. There are a large number of such methods at the moment. We will look at structural and logical schemes as a means of successfully activating learning and cognitive activities and as one of the methods that help to deepen understanding of the material. From the point of view of P.I.Pidkasisty, A.M.Sohor, etc., structuring of learning information is considered as the most important condition for organizing cognitive activity of students, because its didactic goal is rationality and efficiency in learning information and its long-term preservation in memory. Structural and logical schemes are made with the help of reference signals, which represent an associative symbol that replaces a certain semantic meaning that can instantly restore previously known and understandable information in the memory. Logical structuring of learning information provides an opportunity to obtain a clear, well-organized structure, the allocation of which allows to see a system of semantic links between content elements and to arrange these elements in a sequence arising from this system [2]. Designing diagrams assumes that students, together with the professor or independently, analyze and synthesize the issues under study, establish cause-effect relationships, and encourage creativity and nurture a culture of intellectual work. Structural and logical schemes can be used at various stages of the educational process: formation of new knowledge and the conceptual apparatus (assimilation of a new educational material with use of the structural and logical scheme in the form of a reference summary), repetition, generalization of an educational material, the control and account of knowledge [3]. A distinction is made between support and logical schemes, mental maps and timelines. We used the reference and logical schemes as a brief outline of a section or theme of a subject, the mental map as a generalization of the studied material and knowledge control, and the timelines as an organization of an individual educational pattern.

1. Supporting logic circuits. Almost any subject can be represented by reference logic circuits, especially the subjects of the natural science cycle: mathematics, computer science, physics, chemistry, ecology, etc. For example, figure 1 shows the support logical circuit of the section "Indefinite integral" of the Mathematics.

Supporting logic circuits are used to highlight the main content of a topic or section, to generalize it based on leading mathematical theories.

In the process of explaining the new topic, the material is presented in parallel and a supporting logical circuit is constructed. The professor explains what relationships exist between individual concepts and laws and how they are implemented in the scheme. During this discussion, it becomes clear what exactly is already known to students, and what material is quite new. Using this technique helps students study other parts of the discipline themselves during the semester. The use of logical frameworks makes it easier for students to perceive and understand the discipline [4]. For example, it is possible to show and to comment on the study of "Indefinite Integral" with the help of an appropriate reference and logical scheme (figure 1), and to offer the study of the topics "Indefinite Integral" and "Applications of a Definite Integral" independently, having previously prepared a reference and logical scheme and recommending materials to study.
Besides, it is necessary to briefly acquaint the students with the methods and rules of constructing support logic circuits. Namely, it is necessary to explain that structuring the content of educational information begins with the identification of basic learning elements and establishing links between them. A learning element is a logically completed part of information that should be assimilated. Structuring is created by the totality of learning elements included in certain relationships. The following types of relationships can be identified: species, participatory and associative. Species relationships are represented graphically as a fan or tree without arrows. Partitive relations are depicted as a "rake": single parts are depicted with one line and plural parts with two lines. Associative relationships are represented by one trait with bidirectional arrows [5]. A structural and logical analysis of the content, i.e., the learning elements themselves and the relationships between them, should be carried out in order to draw up a future diagram of learning elements. The selected learning elements should be differentiated by the levels of assimilation of concepts: acquaintance, reproduction, application, transformation. Then it is necessary to identify the supporting and new concepts. New knowledge and methods of mental and practical activity are formed on the basis of reference notions. Different connections are possible between supporting and new concepts, which determines the structure of the learning material [6]. The above mentioned referential and logical scheme summarizes the topic "Indefinite integral" (figure 1).

![Diagram](image)

**Figure 1.** Supporting Logical Circuit «Indefinite Integral».

For each element of this scheme, a similar reference logic scheme can be created, reflecting more specific relationships between concepts. For example, for the topic "Integration of Fractional Functions", the reference logical circuit is shown in figure 2.

It should be noted that the reference logical circuits can be: a linear structure, when the previous learning element is connected only with the subsequent one; a tree-like structure, in the shape of a deductive graph (with the original learning element at the top, the presentation is from general to private, figure 1) or inductive graph (with the initial learning element at the bottom, presentation is from private to general); semantic networks (used to reveal the concept’s scope, i.e., as they are constructed, not only the concept’s scope is extended, but also interconnections with neighboring concepts are established) [6]. Most often, reference logical schemes combine different structures and types of relationships (figure 2).

It is recommended to follow the rules when constructing reference logical circuits:

- The scheme is built from top to bottom;
- In any scheme there should be one element corresponding to the beginning;
- There must be at least one path from the beginning of the scheme to any element;
- The contents of all the elements in a scheme must be in the same direction (horizontal or vertical);
- The lines must be parallel to the lines of the outer frame of the scheme elements (the borders of the sheet on which the scheme is depicted);
- The direction of the line from top to bottom and from left to right is taken as the main one and may not be indicated by arrows, in other cases the direction of the line is indicated by arrows;
- The line direction is changed at an angle of 90 degrees.

![Integration of fractional-rational functions](image)

**Figure 2.** Supporting Logical Circuit «Integration of Fractional-rational Functions».

Reference-logic schemes not only create special visibility at consideration of theoretical questions but also show interrelation and logic of transitions between terms and concepts, their logical transformation into laws, principles, theorems. At the same time, each student learns to highlight the main thing, develops logical thinking and unconventional view of the subject, which is very important when studying mathematical disciplines in the context of modern engineering thinking. Therefore, it is hardly reasonable to memorize the schemes themselves, but their construction should be assimilated by the student so that he could independently reproduce and apply the concepts (regulations, principles, laws, theorems) of the topic under consideration in their logical relationship [7].

2. Mental map. By its very nature, a mental map is a structural-logic scheme used to represent associations on a particular topic that are linked and placed around a keyword. Mental maps are most often used to generate, structure, and classify information, which allows for easy reproduction of basic ideas from memory based on visual images. We have used mental map as a feedback tool to control and account for learning, to build logical, causal, semantic, associative, and other relationships between concepts within a single topic and within a module between several topics. Figure 3 shows examples of mental map created by students repeating the theme "Integral Calculation of a Single Variable Function". They are far from perfect and have flaws. But, on the one hand, they illustrate well the
different approaches used by students to structure and visualize learning material and, as a graphical method of presenting information, contribute to the development of creative, projecting abilities of students, provide an opportunity to project reality itself and interpret it in their own way. On the other hand, mental maps allow monitoring and correcting cognitive difficulties of students in studying a specific topic [8]. It should be noted that this method of monitoring and correction of students' knowledge, in contrast to standard methods (control, testing), is more comfortable and does not entail stress but, on the contrary, most often leads to positive emotions.

It is recommended to follow some rules when drawing up mental map:

- The mental map is drawn up on white non-linear paper of A4 (A3) format; the sheet is placed horizontally.
- The main image of a theme (module), task or area of knowledge (for example, "Integral") is placed in the center. From the main image (from the center to the periphery) come branches with signatures, which illustrate the relationship between sections, subsections and concepts of the theme.
- It is recommended to use different types and thicknesses of lines for marking of branches. Thinner lines are used as you get away from the main image. Relationship between objects is specified by arrows.
- All branches at the top shall be signed with one or two key words in block letters. The keyword helps to remember a large block of information. The length of a branch is equal to the length of the keyword (for illustration and efficient use of the sheet space).
- It is recommended to use various visual images of form, color, volume, font, arrows, symbols, symbols (for example, if you use separation of branches with different colors, the main information blocks will be better visible, and the use of pictures will allow to remember the information much faster).

Figure 3. Mental maps «Integral Calculation of a Single Variable Function».

There are various mobile applications and computer programs to create mental maps. However, we recommend that you create them "by hand" for more detailed study and memorization of the studying material. It is important that each student develops his or her own style, which will allow him or her to remember a lot of information and to be able to use it well.

3. Timelines. These structural and logical schemes are ideal for visualization of time processes and sequential presentation of events. With their help it is possible to visualize a schedule of studying of material with indication of terms of performance of current certification works. We use time lines to work with students on an individual learning trajectory.
3. Conclusion
For most students "Mathematics" is a complex subject. The use of non-standard means and methods in
the learning process makes learning its sections interesting and exciting. Having mastered the methods
of drawing up of structural and logical schemes, students can easily cope with large amounts of
information, showing their cognitive independence, and the teacher - to exercise operational control
over their learning material. The offered technique assumes realization of the individual creative
approach, formation of professionally necessary qualities of the future experts in the conditions of
digitalization of education when changes concern ways and the form of transfer of knowledge,
interaction of participants of educational process. Structural and logical schemes contribute to the
formation of learning skills related to the perception, processing and exchange of information (abstract,
annotation, participation in discussions, drafting reports, writing essays, etc.); organizational and
activity skills aimed at solving complex or applied problems; development of all types of memory (short-
term, long-term, semantic, figurative, etc.); the ability to carry out monitoring of cognitive and personal
developments of students, timely detect various difficulties in learning and provide timely assistance in
overcoming them.

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