CONCEPT MAPS AND INFOGRAPHICS AS TOOLS FOR STRUCTURING KNOWLEDGE IN TECHNICAL EDUCATION

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Annotation: The article considers concept maps and infographics as structural-logical visualization tools that help students of technical specialities organise knowledge into coherent systems. The theoretical foundations of concept mapping proposed by J. Novak and D. Gowin, the meta-analytic evidence of J. Nesbit and O. Adesope, the reference signal method of V.F. Shatalov and the sign-symbolic approach of N.G. Salmina are analysed, together with E. Tufte's principles for the design of data graphics. The role of student-constructed maps in comparison with ready-made ones is discussed. Ways of using concept maps and infographics within course modules of electrical engineering and machine elements are described, and their application as instruments of formative and summative assessment is substantiated.

Keywords: concept map, infographics, knowledge structuring, reference signals, data graphics, technical education, electrical engineering, machine elements.

One of the characteristic difficulties of students in technical specialities is the fragmentation of their knowledge. A student may know Ohm's law, the definition of reactance and the formula of active power, may be able to solve standard problems on each topic, and yet fail to understand how these concepts relate to one another within the theory of alternating current circuits. Similarly, in the course of machine elements, the calculation of shafts, bearings, keys and gears is often studied as a sequence of separate procedures, while the logic of the design process as a whole remains hidden. Overcoming this fragmentation requires didactic tools that make the structure of knowledge explicit and visible. Concept maps and infographics belong to such

structural-logical tools, and their systematic use is consistent with the national priority of improving the quality of education and the competitiveness of graduates outlined in the “Uzbekistan – 2030” strategy [1].

The theoretical foundation of concept mapping was developed by J. Novak and D. Gowin on the basis of D. Ausubel's assimilation theory of meaningful learning [2]. According to this view, meaningful learning occurs when new information is deliberately related to relevant concepts already present in the learner's cognitive structure, as opposed to rote learning, in which information is stored arbitrarily. A concept map is a graphical representation of a set of concepts connected by labelled links, so that each pair of linked concepts forms a proposition, that is, a meaningful statement. Novak and Gowin stress the hierarchical organisation of maps, from more general and inclusive concepts at the top to more specific ones below, and attach special importance to cross-links, which connect concepts from different segments of the map and testify to integrative reconciliation of knowledge [2]. For technical education, this approach is valuable precisely because engineering knowledge is relational: a formula expresses a relationship among quantities, and its meaning cannot be grasped without understanding those relationships.

The effectiveness of concept maps has been examined in a substantial body of empirical research. The meta-analysis by Nesbit and Adesope synthesised experimental and quasi-experimental studies on learning with concept and knowledge maps and found that their use was associated with increased knowledge retention in comparison with activities such as reading text passages, attending lectures and participating in class discussions [3]. The benefits were observed both when students studied maps prepared by others and when they constructed maps themselves, across different educational levels and subject areas [3]. These findings provide an evidence base for the integration of concept maps into the teaching of technical disciplines,

although they also suggest that the effect depends on how maps are used and should not be treated as automatic.

In the national pedagogical tradition of the post-Soviet space, ideas close to concept mapping were developed independently. V.F. Shatalov proposed the method of reference signals, in which the content of a topic is condensed into a compact sheet of symbols, abbreviations, schematic drawings and key formulas connected into a whole [4]. Such a sheet serves as an external support for memory and reasoning: the student reconstructs the full content of the topic by "unfolding" the signals during oral answers. Although Shatalov worked primarily with school mathematics and physics, the principle of compressing a large volume of content into an integral visual structure is directly applicable to the courses of higher technical education. N.G. Salmina, in turn, substantiated the role of sign-symbolic activity in learning and showed that modelling and schematization are not merely auxiliary techniques but essential components of the formation of theoretical thinking [5]. From this perspective, constructing a concept map or a reference signal sheet is a form of modelling activity in which the student transforms the content of the subject into a new symbolic form.

Infographics complement concept maps by combining graphical and verbal elements to present processes, comparisons, classifications and quantitative information in a compact visual form. Unlike a concept map, which shows the conceptual structure of a domain, an infographic often shows the structure of a process or a data set: the sequence of stages in designing a gear drive, the classification of electrical machines, a comparison of the characteristics of different bearing types, or the energy balance of a transformer. The effectiveness of infographics depends heavily on the quality of their design. E. Tufte formulated principles for the display of quantitative information that remain highly relevant for educational graphics [6]. Among them are the maximisation of the data-ink ratio, meaning that most of the ink in a graphic should represent data rather than decoration; the avoidance of chartjunk,

such as unnecessary grids, patterns and pseudo-three-dimensional effects; graphical integrity, according to which the visual representation of numbers should be proportional to the numerical quantities represented; and the use of small multiples, which allow comparison of a series of similar graphics with the same design. For engineering students, adherence to these principles has a double benefit: it improves the clarity of learning materials and forms the culture of presenting technical data that is required in professional practice.

A key methodological question is whether students should receive ready-made maps and infographics or construct them themselves. Ready-made materials prepared by the teacher ensure correctness and can serve as advance organisers at the beginning of a module or as summaries at its end. However, the construction of a map by the student requires selecting key concepts, determining their hierarchy and, above all, formulating the nature of the links between them. This activity reveals gaps and misconceptions that remain hidden during passive reading. It also develops visual literacy, understood as the ability to interpret and create visual representations with awareness of their conventions [7]. In the practice of technical education, a combination of both approaches appears reasonable: the teacher offers a skeleton map with the main concepts at the beginning of a topic, and students progressively expand it, adding concepts, links and examples as the study proceeds.

The use of these tools can be illustrated by the module "Alternating current circuits" of the electrical engineering course. At the introductory lecture, students receive a partially completed concept map with the central concept "sinusoidal current" and first-level concepts such as "parameters of a sinusoid", "circuit elements", "phasor representation" and "power". During subsequent classes, they add concepts such as amplitude, effective value, phase, resistance, inductive and capacitive reactance, impedance, active, reactive and apparent power and power factor, and label the links between them, for example "inductive reactance increases in proportion to

frequency" or "power factor characterises the share of active power in apparent power". At the end of the module, students prepare an infographic comparing the behaviour of resistive, inductive and capacitive elements, which, following Tufte's principles, should present phase relationships and frequency dependencies in a uniform format suitable for comparison.

In the course of machine elements, the emphasis shifts from conceptual structure to the logic of design. Here a useful tool is a process infographic showing the sequence of designing a drive: the selection of an electric motor, the kinematic calculation, the design of gears, the design of shafts, the selection of bearings and couplings and the verification calculations. A concept map built around the concept "shaft" can connect loads, materials, failure criteria, stress concentration factors and the methods of strength and stiffness calculation. Such a map reveals that the calculation of a shaft is not an isolated procedure but an application of concepts studied earlier in theoretical mechanics and strength of materials, thereby establishing interdisciplinary links that students often fail to notice.

Concept maps also have significant potential as assessment instruments. Since a map externalises the student's knowledge structure, it allows the teacher to evaluate not only whether certain concepts are known, but how they are interconnected. Novak and Gowin proposed scoring a map on the basis of valid propositions, levels of hierarchy, cross-links and examples, with cross-links weighted more heavily because they indicate integrative understanding [2]. In formative assessment, the comparison of maps constructed by a student at the beginning and at the end of a module shows the evolution of his or her knowledge structure, and the analysis of incorrect links helps the teacher identify typical misconceptions, for instance the confusion of reactive power with power losses. In summative assessment, map construction tasks can supplement traditional problems, assessing the systematic character of knowledge that numerical problems do not capture. Such use corresponds to the broader principles of

pedagogical technologies, which require clearly defined learning objectives and diagnostic means for verifying their achievement [8].

The practical introduction of concept maps and infographics in technical education requires attention to several conditions. Students should first be taught the technique of map construction on simple and familiar material; otherwise, the effort of mastering the format itself will hinder the learning of content. The number of concepts in a single map should be limited, and large topics should be divided into linked submaps. The teacher should agree with students on a consistent system of shapes, colours and link types. Finally, digital tools for map construction can be used, but they should support rather than replace the intellectual work of formulating propositions.

In conclusion, concept maps and infographics are effective tools for structuring knowledge in technical education, as they turn the implicit relational structure of engineering knowledge into an explicit visual form. Their theoretical basis lies in the theory of meaningful learning, in the national tradition of reference signals and sign-symbolic activity, and in the principles of rational data graphics, while empirical research supports their positive influence on knowledge retention. Their use within course modules, especially in the form of student-constructed maps, and their application as assessment instruments, can contribute to overcoming the fragmentation of knowledge and to the formation of systemic engineering thinking.

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