THE ROLE OF TECHNICAL DISCIPLINES IN THE FORMATION OF THE STUDENT'S ENGINEERING THINKING

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Abstract: *The article presents the concept of thinking, the necessary conditions for its inception and development. Since the modern labor market presents a wide range of requirements for a modern engineer, the approach to the formation of engineering thinking should also be revised. It is noted that engineering thinking is the result of four components of knowledge and skills, the formation of which begins as early as the preschool age. This article describes the process of formation of engineering thinking on the example of students of the area "Agroengineering" of the Northern Trans-Urals State Agricultural University. The composition of the training complex "Mechanics" is presented in the form of separate successive disciplines and stages in the formation of thinking. The main results of studying each discipline in the process of forming the student's engineering thinking are described. The possibility of using informational technologies for solving specific engineering problems is considered.*

Keywords: thinking; mechanics; disciplines; stages of formation; training.

Over the past 50 years, scientific and technological progress has made a powerful breakthrough in its development, changing the rhythm of life, priorities and thinking of man. Modern discoveries and developments not only allow accelerating the processes of manufacturing and improving products, but also oblige educational institutions to prepare competent specialists that meet modern requirements. The main basis of the engineer is his ability to analyze, study and solve the task, that is, his ability to think. Thinking is a socially conditioned, inseparably connected with the speech cognitive mental process, characterized by a generalized and indirect reflection of the connections and relationships between objects in the surrounding reality[1]. For the emergence of thinking, it is necessary to practice communication and objective activity, which allows giving an adequate image of the object under study, to identify existing and possible connections both inside and between objects. To "start" the process of developing engineering thinking, the main means of development is practical action. And only then, with developed thinking, the thought itself becomes a means for organizing the action.

[1] Z.S. Sazonova, N.V. Chechetkina. *Development of engineering thinking-the basis for improving the quality of education,* MADI, Moscow, 2007.

Turning to history, it can be clearly seen that engineering thinking allowed people to create engineering structures that still cause admiration, facilitate their work, master new technologies used for development and evolution. In the process of formation and development of engineering thinking, certain stages are singled out, including the creation of the first educational institutions, engineering inventions and breakthroughs in science.[2] The current stage in the formation and development of engineering thinking is associated with information technology that allows one to perform tasks in a shorter time[3,4]. But in order to master new technologies, it is necessary to learn the basics of engineering, to get acquainted with the main discoveries and regularities that modern technologies and technical means are subject to[5].

Methodology

The modern labor market sets quite high demands on the engineer. Every year the scope of the engineer's activity is increasingly transformed from solving specific professional tasks to problem solving and project management[6]. New technologies used in production require specialists to be able to think constructively and critically, to be able to determine and reconfigure goals "along the way" in accordance with new requirements and to act on several options for the development of the process. If engineers of a narrow profile were earlier in demand, the modern engineer is a universal in all spheres of engineering with knowledge of a foreign language, able to create business plans. Interest in technics should be awakened in a person at an early age, so that over time, he was able to

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[2] A.Yu. Rozhik, "Historical stages of solving the problem of the formation of engineering thinking", in *Bulletin of the South Ural State University,* 2017, vol. 18, no. 3, p. 113-115.

[3] V.Yu. Bodryakov, O.B. Nigomatova, T.S. Tveritina, *Formation of the fundamentals of engineering thinking of students in the process of solving optimization problems using ICT*. V Interregional Full-Time Scientific-Practical Conference with International Participation "The Role and Place of Engineering Knowledge in the Structure of General Education", 2017, Saint Petersburg, p. 213-216.

[4] R.M. Abdulov, E.V. Abdulova, "Application of modern information and communication technologies in the formation of engineering thinking in the process of teaching physics", in *Pedagogical Education in Russia,* 2016, vol. 6, p. 8-14.

[5] O.V. Zashchirinskaia, A.V. Lapteva, E.I. Nikolaeva, N.A. Medina Bracamonte, E.V. Zmanovskaya, "Concepts of friendship among primary school children with intellectual disability", in *Novosibirsk State Pedagogical University Bulletin*, 2018, vol. 8, no. 2, p. 26-42.

[6] L. Mylnikov, R. Fayzrakhmanov, D. Kurushin, "Information support of project management processes in the network of research organizations and technological companies", in *Astra Salvensis*, 2018, vol. 6, p. 603-612.

show his abilities and level of thinking. The formation of a future engineer starts at school when studying mathematics, physics, drawing, etc. It is here that a pupil begins to show his attitude to constructive and exploratory thinking.[7] Figure 1 shows the structure of engineering thinking as a component of several separate types of thinking.

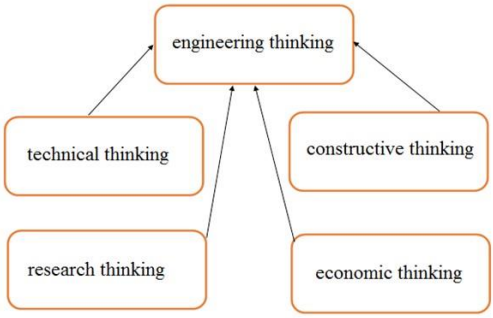

Figure 1: Structure of Engineering Thinking

technical thinking – the ability to analyze the principle of operation and maintenance of technical facilities;

constructive thinking – the ability to create models and develop methods for solving the problem;

research thinking – the ability to find the novelty of the task, to argue the course of one's thoughts and to confirm the results

economic thinking – evaluation of the quality and effectiveness of the solutions obtained.

All these described skills should be formed in a person step by step and in a certain order. In the school years, engineering thinking is developed in various ways (project works, experiments, inventions, etc.) and at the final stage; a pupil should have fundamental knowledge and skills that he should rely on in choosing the engineering direction at the university. This knowledge will be necessary for the development of spatial thinking and constructive approach to the solution of the task. The ingenuity (research thinking) of the future engineer allows non-standard analysis of everyday things and creating new mechanisms and details that were not previously available. For example, postgraduate students of the SAU of the Northern Trans-Urals came up with the idea to use of the properties of tubular elements used in instrument-making, in the

[7] I.V. Mankova. *Formation of engineering thinking in the process of teaching natural science disciplines.* The International Scientific and Practical Conference "Formation of Engineering Thinking in the Learning Process", 2015, Ekaterinburg, p. 118-121.

construction of machines for tunneling[8] or to direct the exhaust gases of ICE of tractors on a special highway in order to reduce adhesion between the ground and the bucket surface during trench digging[9].

Results and discussion

At the first years of engineering training, a student faces general technical disciplines that together form the training block "Mechanics". When teaching students in the SAU of the Northern Trans-Urals in the area 35.04.06 "Agroengineering" for three years students study "Mechanics" in the following sequence (Table 1).

Table 1: Sequence of Study of General Technical Disciplines in the SAU of the Northern Trans-Urals

Name of the discipline	Term					
	1	2	3	4	**5**	**6**
Descriptive geometry	+					
Engineering graphics		+				
Theoretical Mechanics		+	+			
Strength of materials			+	+		
Theory of mechanisms and machines				+	+	
Machine parts and design basics					+	+

This sequence of disciplines provides a systematic approach and creates a comprehensive model of engineering thinking.[10] When studying "Descriptive Geometry" and "Engineering Graphics" the student develops spatial and creative thinking[11]. The development of these abilities

[8] S. Kokoshin, S. Sozonov, S.I. Shestopalov. "Theoretical justification of reducing soil adhesion to the surfaces of the excavator working body at creation underground infrastructure", in *Procedia Engineering,* 2016, vol. 165, p. 829-838.

[9] S. Kokoshin, N. Ustinov, B. Kirgincev. "The use of flexible tubular elements of the overhaul and tunnels reconstruction", in *Procedia Engineering,* 2016, vol. 165, p. 817-828.

[10] N.N. Makovskaya, G.Yu. Churin, "Methods of system engineering in the formation of engineering thinking", in *V Interregional Full-Time Scientific-Practical Conference with International Participation "The Role and Place of Engineering Knowledge in the Structure of General Education"*, 2017, Saint Petersburg, p. 178-182.

[11] E.L. Hasanov, V.D. Panachev, V.P. Starostin, A.G. Pudov, "Innovative approach to the research of some characteristics of choir scenes as culturology issue", in *Astra Salvensis*, 2018, vol. 6, no. 1, p. 749-759.

makes it possible to disclose the modeling and ingenuity in the student.[12,13] If you pay attention to educational standards, then these disciplines were included in the basic part of theoretical training, and FSES 3+ contains professional competencies that are formed by these disciplines. Practical activity of the student at this stage involves graphically solving tasks for flat and spatial relations between objects (point, line, plane, surface). As a result of the analysis of certain tasks, a teacher develops judgment and reasoning in the students. For the analysis of assembly objects, the student should learn to perform the following mental operations[14]:

– comparison (determine similarities and differences between objects);

– analysis (partition of the assembly unit);

– synthesis (determine the possibility of articulation of objects);

– synthesis (defining common attributes);

– specification (comprehension of the object taking into account the specificity).

For the correct formation of the above-mentioned thought operations, an individual approach is required from the teacher.[15] The teacher, by all possible means, awakens and activates the students' independent search for the solution of the task in question, and in case of great difficulties indicates, shows only the general direction of searches, so that students perform the main part of the mental work on their own. To do this, visual representations in the form of layout, demonstration models or 3D-images are used.[16] As a result of studying these disciplines, the student should develop spatial thinking that allows analyzing the mutual position of objects in space or to form imaginatively the shape of the object according to its projections. Figure 2 shows one of the ways of the mutual position of straight lines in space.

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[12] K.V. Vasilyeva, A.P. Chuvashev, "Formation of creative technical thinking in the process of teaching engineering graphics in higher education", in *The International (Virtual) Scientific and Practical Conference "Integration of Science and Practice in Modern Conditions"*, 2017, Neftekamsk, p. 183-187.

[13] V.I. Seregin, L.R. Yurenkova, "The role of graphic disciplines in the formation of engineering thinking of students", in *Engineering Bulletin,* 2014, vol. 9, p. 27.

[14] Z.S. Sazonova, N.V. Chechetkina, *Development of engineering thinking – the basis for improving the quality of education*, MADI, Moscow, 2007.

[15] M.R. Shabalina, M.V. Khokhlova, I.V. Sitnikova, "Pedagogical potential of mathematical education in the process of formation of the engineering style of thinking", in *Almanac of World Science,* 2011, vol. 18, no. 3-2, p. 113-115.

[16] N.I. Ibragimova, "Operationalism in the formation of geometric objects and its influence on the formation of engineering thinking", in *International Journal of Experimental Education,* 2012, vol. 12, no. 1, p. 82-83.

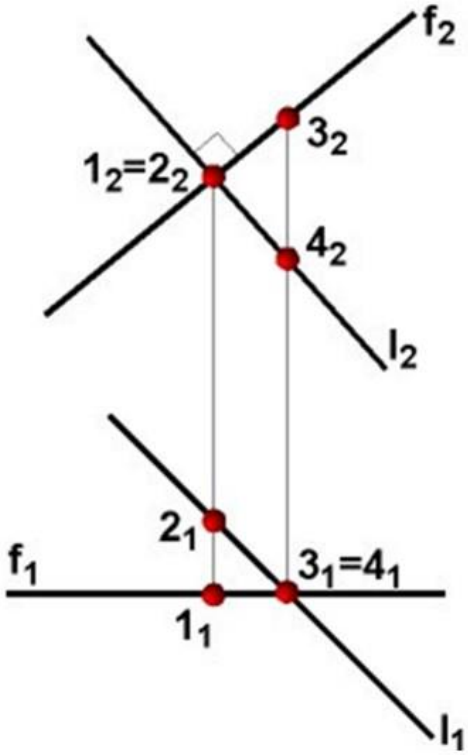

Figure 2: Mutual Position of Straight Lines in Space

A person who does not have spatial imagination can hardly be explained that there are crossed straight lines on the figure. But if we show the position of these straight lines with the help of two pencils, then practically everyone understands why the lines in the projections intersect at different points. These capabilities enable the engineer to model the design according to the assembly drawing or to correctly select the workpiece and the sequence of technological operations for the production of a particular detail.

The next substantive stage in the development of engineering thought is Theoretical Mechanics and Strength of Materials. These disciplines allow the student to apply the knowledge of mathematics and physics on specific examples. At this stage, he learns to create computational schemes of real objects, applying already formed spatial thinking and using the operations of synthesis and specification. Getting the final result as specific parameters of certain design details allows the student to comprehend the applied application of knowledge of mathematics and physics. In the design calculations, the student should give a reasoned conclusion about the choice of a material for the design

structure. Here the student needs to be explained that the task from the viewpoint of strength has several correct solutions and only economic analysis will allow identifying the optimal result.

The use of information technology in complex calculations of certain designs enables the student to analyze modern engineering capabilities and determine the scope of their application. Such application programs as MathCAD, MatLAB allows creating an algorithm for calculating the strength and rigidity of structures, and the integration of programs with SolidWorks makes it possible to visualize the results. The use of applied programs in conjunction with the training experiment allows for a higher level to realize the experimental and research activities of students. In addition, the integrated use of such tools makes it possible to expand students' ideas about modern methods of scientific research, methods of automated manufacturing and processing of materials used in production.

The technical capabilities of digital virtual laboratories in the educational process make it possible to measure the required parameters by means of various sensors and to monitor their changes in real time, and the data obtained in the course of the experiment can be represented in different variants in the form of graphs, data tables, etc.[17] At that moment the student feels himself an explorer, he possesses the process of experience and analysis. It is at this stage that it is already possible to identify potential researchers and to turn them against the further study in the master's program.

The next stage in the formation of the future engineer is the study of disciplines "Theory of Mechanism and Machines" and "Machine Parts and Design Basics". They already combine the computational knowledge and graphic skills of the student, forming certain professional competences. The application of virtual laboratories and real stands allows the student to compare the scope of application of the obtained knowledge[18]. For example, laboratory work on the static and dynamic balancing of a rotating disk allows the student to understand what the principle of the wheel balancing machine is based on (Figure 3).

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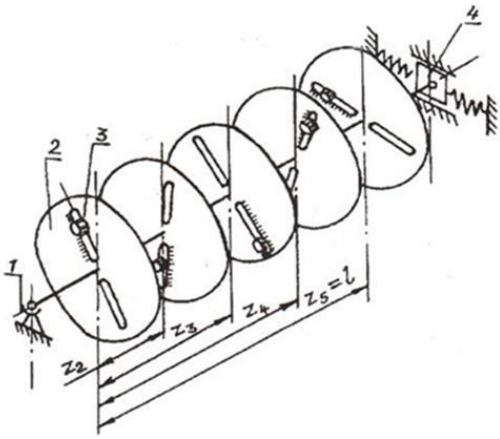
[17] I.N. Semenova, T.A. Ryabova, "Revisiting the question of the possibility of using mathematical modeling for the formation of engineering thinking in students", in *The International Scientific and Practical Conference "Pedagogical and Psychological Technologies in the Conditions of Educational Modernization"*, 2017, Ufa, p. 215-218.

[18] I.S. Volegzhanina, S.V. Chusovlyanova, E.S. Bykadorova, J.V. Pakhomova, "Ontology-based virtual learning environment for academic knowledge co-management (by an example of transport universities)", in *Astra Salvensis*, 2018, vol. 6, p. 787-796.

a)



b)

Figure 3: Units for Balancing Rotating Discs: a – scheme of laboratory unit TMM-35M; b – balancing machine for automobile wheels

Writing the course work on designing a drive for a particular working machine enables the student to feel himself at the designer's place. Being responsible for the project, he makes specific proposals based on the analysis of data, their comparison to analogues, determining the optimal variant. One of the main indicators of the choice of the optimal solution is its economic efficiency. Graphical part of the proposed design solutions is implemented using modern engineering applications: Compass 3D, AutoCAD, SolidWorks. This stage reflects the knowledge of the standards of the unified design documentation system (UDDS) obtained in the study of the discipline "Engineering Graphics".

As a result of studying this set of disciplines, the student must have a fundamental engineering knowledge. Further studying related to a certain type of activity or specialization, allows applying the knowledge gained directly to practice in a particular field.

At present, the formation of engineering thinking starts since the preschool age. Modern technologies allowed creating an informational Internet resource УЧИ.ру (https://uchi.ru/). At first glance, fairly simple tasks are presented there, but they allow the child to already think constructively, not yet knowing the laws of physics and mechanics, and by results one can judge about the further development of the child as a "technician".

Traditional higher education implies the transfer of ready knowledge to students, but the disadvantage of this process is the lack of student's independence and illustration of his creativity. For a modern engineer, it is necessary to provide freedom of thought, an abstract and creative approach to solving standard and unusual situations, to allow him to model an object that could have never existed. The creation of the new distinguishes an engineer from a scientist who studies what already exists.