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### **TASK SOLVING AS THE BASIS OF MATHEMATICAL PREPARATION OF FUTURE ENGINEERS**

The results of the study of the problem of solving mathematical tasks in the preparation of future engineers are revealed. The urgency and importance of the topic is substantiated by the need of Ukrainian enterprises in qualified specialists of engineering specialties and the need of the society to ensure high quality of education. An approach to task solving in higher mathematics is theoretically developed. The peculiarities of its practical implementation are clarified. Guidelines and steps for solving problems are explained. Rules for verifying resolved tasks are produced. The errors that future engineers make when solving tasks are classified. The necessity of making changes to the higher mathematics syllabus at the National Technical University "Kharkiv Polytechnic Institute" and the introduction of laboratory works using Mathcad, Matlab, Scilab etc. are substantiated.

**Key words:** task solving, mathematical training, engineers, higher mathematics.

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### **РОЗВ'ЯЗУВАННЯ ЗАДАЧ ЯК ОСНОВА МАТЕМАТИЧНОЇ ПІДГОТОВКИ МАЙБУТНІХ ІНЖЕНЕРІВ**

Статтю присвячено найголовнішому аспекту математичної підготовки майбутніх інженерів – розв'язуванню задач. Теоретично розроблено підхід до розв'язування задач з вищої математики. Розкрито особливості його практичної реалізації. Виявлено методичні рекомендації та етапи розв'язування задач. Висвітлено правила перевірки розв'язаних задач. Класифіковано помилки, яких припускаються майбутні інженери під час розв'язання задач. Досліджено структуру практичного заняття для ефективного вирішення поставленої проблеми. Рекомендовано схему самоаналізу викладачем проведеного заняття. Підтверджено високий результат розв'язання математичних задач на студентських заняттях.

**Ключові слова:** розв'язування задач, математична підготовка, інженер, вища математика.

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### **РЕШЕНИЕ ЗАДАЧ КАК ОСНОВА МАТЕМАТИЧЕСКОЙ ПОДГОТОВКИ БУДУЩИХ ИНЖЕНЕРОВ**

Статья посвящена важнейшему аспекту математической подготовки будущих инженеров – решению задач. Теоретически разработан подход к решению задач по высшей математике. Раскрыты особенности его практической реализации. Выявлены методические рекомендации и этапы решения задач. Выработаны правила проверки решенных задач. Классифицированы ошибки, которые делают будущие инженеры при решении задач. Исследована структура практического занятия для эффективного решения поставленной проблемы. Рекомендована схема самоанализа преподавателем проведенного занятия. Подтвержден высокий результат решения математических задач на студентских занятиях.

**Ключевые слова:** решение задач, математическая подготовка, инженер, высшая математика.

**Introduction.** The urgency of the problem of mathematical training for future engineers is substantiated by the objective need of Ukrainian enterprises in highly qualified engineers and the need of the society to provide high quality technical education. There exist an obvious link between this problem and the important theoretical and practical tasks of specialist training stated in the Law on Higher Education adopted by the Verkhovna Rada of Ukraine. This Law establishes the basic principles of the functioning of the higher education system in order to prepare competitive human capital for the high-tech and innovative development of the country, self-realization of the individual, to provide the needs of society in skilled specialists [1].

**Analysis of recent studies.** The results of the analysis of recent research and publications indicate that scientists are interested in the problem as a whole (*V. Andrushchenko, V. Kremen* and others) and its individual aspects (*S. Skvortsova, L. Suhina* and others). Academician *V. Andrushchenko* argues for a greater focus on fundamental disciplines. Scientist emphasizes demonstrations of public disregard for them and predicts serious material losses and social miscalculations as a result [2].

The Commission of the European Mathematical Society, which pays close attention to the current problems of mathematical education for young people, adopted at the level of the European document a scheme of parameters by which the contribution of mathematics to the development of personality could be determined. Thinking and algorithms are attributed to the parameters of general development. The analysis of the scheme allows to conclude that there is a connection between the general parameters of personality development and mathematical knowledge and skills, as well as to identify indicators that indicate the applied orientation of mastering mathematical disciplines [3, 4].

The holistic nature of mathematics is based on the intrinsic essence of this science: mathematics is the basis of all accurate natural and scientific knowledge. The main criterion for testing mathematical knowledge is the ability to solve tasks. Task solving is the process of performing actions, or mental operations, aimed at achieving a goal that is set within a problem situation – a task. This process is also an integral part of thinking [5].

There are different approaches to task solving. Abroad, it is believed that in most problem solving theories, the

process itself consists of:

- identification of problem situation;
- resolution of the task;
- finding a solution to the problem.

Such stages of the problem solving process are found in *O. Zelts, K. Duncker, Greeno* and others [5].

The main distinguishing characteristics of work on tasks in the so-called *L. V. Zankov* system are:

- various forms of short recording;
- analytical method of finding a solution;
- different forms of recording the solution;
- research on a task after solving it.

These stages of task solving are revealed in many pedagogical and developmental teaching textbooks.

*O. Ovchar* demonstrates the need for applied tasks in the study of mathematics and reveals the methods of solving them. It is concluded that solving applied problems systematizes the acquired knowledge and experience, promotes the comprehensive development of mathematical thinking [6].

A new century is a new frontier, a dream, a hope. The logic of real life developments, including university ones, necessitates the introduction of new approaches to task solving. Higher mathematics is the science of the ages, which has its own peculiarities. Moreover, it is a fundamental discipline in technical higher education institutions, which is of immense importance for the engineer.

**The purpose** of the article is to theoretically develop and reveal a practical implementation of an approach to solving mathematical tasks in the preparation of future engineers.

At the National Technical University "Kharkiv Polytechnic Institute" (NTU "KHPI") higher mathematics is studied at lectures and practical classes. Experience has shown that the quality of application of theoretical material depends largely on the ability to solve tasks. The main focus is on task solving in practical classes. So, let's explore this kind of training in higher mathematics at the oldest technical university in Ukraine.

It is well known that a practical class is a training session in which the teacher organizes a detailed examination of the students in certain theoretical topic of the discipline and forms the skills of their practical application by making students individually solve practical tasks [1]. Practical classes are modeled on the basis of the psychological characteristics of future specialists, their level of knowledge in the course of school, professional choice. The following structure of the practical lesson was justified:

1. *Upgrading students' basic knowledge, skills and competences to successfully complete their tasks.*

It is carried out on the basis of the following methods and techniques: setting a problem task, identifying knowledge and skills needed to solve the problem, purposeful activity.

2. *Motivation of educational activity.*

The main impetus for the implementation of a specific practical assignment is the students' awareness of the practical importance of the knowledge, skills and abilities they need to learn in the classroom, for future work in the specialty.

3. *Communication to students of the topic, goals and objectives of the practical work.*

It emphasizes the nature of the independent task, how to approach it, how the results of each student's work will be evaluated.

4. *Independent performance of students' tasks under the supervision of the teacher.*

The complexity of pedagogical treatment of students at this stage is that they have different training, different abilities, which determines the different pace of academic work. All this requires an individual approach to students, differentiation of tasks.

5. *Generalization and systematization of student work results.*

After solving the problems, students analyze the results, organize them using diagrams, tables and more.

6. *Students' report on methods of solving problems, theoretical substantiation of the obtained results.*

On the basis of the obtained results, analysis, comparison, generalization in the form of regularities, conclusions, rational methods of solving problems, the individual work of students is comprehensively evaluated. In particular, the following factors are included in the evaluation of a solved problem:

- what concepts, theorems, facts are involved in the process of solving the problem;
- what are the ways of solving problems;
- how to activate your brainstorming activity.

7. *Summary of the lesson.*

Students report what they have learned in the classroom. The teacher focuses on studying what subject and, in general, where the knowledge acquired today is applied.

8. *Homework.*

You are constantly advised on how to do your homework better.

How to check your homework without wasting time when there are a large number of students in a group? Obviously, without checking the quality of the assimilation of the material, the overall level of training of specialists is reduced. It takes more than 5 minutes for a teacher to review homework and make appropriate entries in his journal. If students ask questions individually, this time is increased three or more times. With today's syllabuses, this situation can lead to negative consequences.

The following rules must be followed to ensure that such work is effectively controlled and effective.

1. Create multiple microgroups. The number is determined by the teacher. Later, if necessary, it is possible to re-compose microgroups to include students with different levels of cognitive abilities. Determine the leader of the microgroup.

2. Motivation of educational activity of each microgroup, promotion of a purpose, comprehension of a form of realization of self-control and self-assessment in all topics which are studied.

3. Getting tasks. Setting terms for finishing them.

4. Identification by the leader of gaps in knowledge when performing homework in such a microgroup. A relatively formed self- assessment.

5. Consultation of the microgroup leaders with the teacher.

6. Student consultation with the microgroup leaders and teacher. Rediscovering gaps in students' knowledge in the course of homework on the same topic by leaders of microgroups.

7. Checking the adequacy of self-assessment of each student belonging to a microgroup by all the microgroup members; setting jointly the grade for each member of the microgroup and the overall score of the microgroup.

8. Supervision of work of microgroups by the teacher. Creating a standard that requires self-control. An analysis of the journals that microgroup leaders provide to the teacher before the class begins. Differentiated work of the teacher with students who have poorly mastered the subject and those who are successful in studying the material.

The advantage of such a technique is that the gaps in knowledge of even those students who have been ill for a long time are eliminated. Practice has shown that only the activity of students in the realization of purpose, self-control, use of knowledge, skills promotes the conscious mastering of educational material by students, forms the ability to think and work independently.

Teacher's introspection of the conducted class facilitates the improvement of the quality of training during practical classes. It is recommended to conduct self-examination according to the following scheme:

1. Characterization of learning opportunities of group students.

2. Students' understanding of the basic concepts, theorems, rules, studied in this topic. What were the tasks of the education, training and development of the students the lesson was designed for?

3. Thoughtful selection of training material, including typical tasks, for the whole class.

4. Argumentation for choice of structure of employment, forms and methods of organization and stimulation of educational and cognitive activity of student, control and self-control.

5. Teaching students the methods of creative cognitive activity.

6. Vocational guidance.

7. The system of repetition of students' educational material.

8. Ensuring students complete their homework.

9. Personal contribution of the teacher and the real contribution of students to mastering the topic.

10. Evaluation of the results of the lesson. Factors that positively and negatively influence the preparation and conduct of the practical training. Suggestions: what to do personally to increase the effectiveness of a practical training course.

The effectiveness of studactive classes in solving the problem of higher mathematics training has been proved. High results are gained by following the technology of studactive classes, including powerful motivation of educational activity, permanent and frequent feedback, individual research, analysis and presentation of scientific and educational information. At studactive classes knowledge is obtained in a conscious and active way, based on research, beliefs, professional orientation. Responsibility is reached immediately. By such conditions future specialists realize what benefits knowledge gives to them and their society and consequently the level of knowledge quality is rising [7 – 10].

A decisive condition for solving a new task is finding an effective strategy for solving it. At the same time, it is known that many students are trying to implement the first or better known strategy, or under the influence of individual fragments of the task, attempt to perform any action with data or numbers. This is largely due to the fact that in modern learning conditions effective methods of solving students' tasks are formed quite often spontaneously. In order to teach the future engineer to solve problems, one must first teach him the approach in which the task acts as an object of careful study, and its solution – as an object of design and invention, a habit of reasoning that gives rich fruits: it develops that special mathematical ingenuity that can help in a variety of situations. Sometimes it can even do an unexpected service,

allowing you to confidently recover a partially forgotten formula. Learning how to "see" and inventively solve problems requires theoretical knowledge, ingenuity and the ability to think.

Our research has shown that the success of mathematical calculations is greatly facilitated by the following methodological recommendations for the step-by-step solution of the task.

*The first stage.* Study and comprehend the condition of the task. Find out what the calculations are, what the problem is, and the conditions under which it is to be solved. The student analyzes the problem.

*The second stage.* Develop the ability of the student to schematically record the task. The consequences of the task analysis should be recorded. The verbal form is little effective. Schematic recording is the widespread use of signs, symbols, drawings etc. The schematic record captures only what is needed to solve the task, and discards all other details that are in the task condition. The step is skipped for simple tasks or when the answer becomes apparent after analysis.

*The third stage.* Make a plan for solving the problem, find a method for solving it. Identify the type of problem it belongs to and apply the corresponding theorem, rule etc.

*The fourth stage.* Completing the task.

*The fifth stage.* Checking the resolved task. The student must make sure that the solution is correct and that it satisfies all the requirements of the task.

*The sixth stage.* Analysis of the solution of the problem. Find out if there is another, more rational way to solve, whether the task can be summarized, what conclusions can be drawn from this solution, determine the interdependence and the relationship between the values given in the task and the found.

Our extensive experience in teaching mathematics has highlighted students' common mistakes in solving tasks. Those relating to linear algebra and analytical geometry can be found in the textbook [11]. We classify all the errors that students make into three types.

*First.* Recording errors. As a rule, they arise due to inattention.

Example.  $(\sin x) = \cos x$ . A derivative sign is omitted when differentiating a function.

*Second.* Substantial errors. They usually occur when students move on to solving problems without studying the theoretical material.

Example. An error can occur when deriving the equations of tangent and normal to the graph of the function  $y = x^{1/2}$  at the origin.

*Third.* All other errors.

How a student will learn higher mathematics, how he / she will solve the tasks depends on the student, the level of knowledge of school mathematics. What will be the learning depends largely on the teacher, his professional training, erudition, ethics and even appearance. The quality of training of future engineers depends on the scientific and methodological literature, didactic material, equipment of the auditorium with modern computers and more.

We live in computer times. Ukrainians own smartphones or iPhones and have 24/7 access to a computer. Even a large proportion of schoolchildren carry gadgets. Well-known companies in the world have fantastic computer technology. A few years later, they predict mass production of gadgets that will be able to execute commands provided by the owner's opinion. Not by pressing keys, not by voice, but by thought.

Is higher mathematics syllabus outdated? Isn't teaching higher mathematics far behind such rapid global progress?

As a result of the analysis of the syllabuses at the Department of Higher Mathematics, the NTU "KPI" it was concluded that they have not changed substantially in the last 25 years. The changes involved a significant reduction in hours with a reduction in mathematical content. The studied material was also regrouped or part of it was assigned for students' self-learning. During this period, some subjects were lost at the department. The part of the content of the liquidated disciplines was introduced as separate sections of "Higher Mathematics", such as, for example, Linear Algebra and Analytical Geometry. At the same time, much of the important mathematical material has disappeared, such as, for example, mathematical statistics, despite the well-known applied nature of problems in probability theory and mathematical statistics.

Therefore, we suggest a major revision of the syllabuses in higher mathematics and other mathematical subjects, eliminate unnecessary duplication of school mathematics, get rid of some topics, enrich the discipline with new sections, taking into account the wishes of specialized departments. Today, you can offer first year students, such as 123 Computer Engineering majors, to solve some problems using Mathcad. Such engineering software allows you to make important calculations and analyze them. The mathematical preparation of future engineers will only benefit from such an innovation. Moreover, the necessary material and technical base exists in the NTU "KPI".

Deploying Mathcad requires no additional workload. Introduce changes to the syllabus by replacing some of the lab classes. The contents can be reduced by assigning some topics in the sections "Derivative of a function of a single variable" or "Linear algebra and analytic geometry" for students' self-learning providing them with study guides with accessible and detailed material.

We also propose to use the Matlab platform, specially designed for engineers and scientists, when studying higher mathematics. We pay attention to Scilab – a package of applied mathematical programs for engineering, technical and scientific calculations. This is the most comprehensive of the available Matlab alternatives [5].

**The prospect of further exploration** in this direction is a more detailed study of the students' typical mistakes in solving problems and methods of their elimination.

**Conclusions.** Thus, task solving is a complex and necessary process for future engineers. Learning to solve them is a common problem of the student and the teacher. Our approach to task solving takes into account not only the features of higher mathematics, but also the professional orientation and specialization of the engineer. The well-researched structure of the practical class allows you to form the skills and competencies that are necessary for successful completion of the tasks. It has been found out that self-analysis of the conducted lesson by the teacher helps to increase the quality of knowledge. The scheme of such introspection is recommended. The guidelines and steps of solving the tasks are disclosed. The rules for quick checking the out-of-class unsolved tasks are suggested. All the mistakes that students make when solving tasks are divided into three types, such as writing errors, content errors and others. The proposition to change syllabuses in mathematical subjects at the NTU "KPI" is substantiated. We suggest to eliminate unnecessary duplication of school mathematics, get rid of some topics, enrich the discipline with new sections of modern mathematics. Moreover, we recommend to introduce into the educational process laboratory work using Mathcad, Matlab, Scilab etc. The high efficiency of studactive classes in solving this problem is highlighted.

#### Bibliography

1. Закон України «Про вищу освіту». – Голос України. – 6 серпня 2014. – № 148 (5898). – С. 9 – 19.
2. Андрущенко В. П. Роздуми про освіту : статті, нариси, інтерв'ю. – К. : Знання України, 2005. – 804 с.
3. Олексенко В. М. Інноваційні підходи до викладання математичних дисциплін // Нові технології навчання : наук.-метод. зб. – К. : НМЦ "Немішаєве", 2014. – Вип. 80. – С. 6 – 9.
4. Башмаков М. И. Мы учим и учимся математике в нашем общем доме – Европе // Математика в школе. – 2002. – № 1. – С. 3 – 6.
5. Wikipedia. Problem solving. – Режим доступа : [https://en.wikipedia.org/wiki/Problem\\_solving](https://en.wikipedia.org/wiki/Problem_solving). – Дата обращения : 05 октября 2019.
6. Овчар О. Методи розв'язування прикладних задач // Молодь і ринок. – 2010. – № 10 (69). – С. 145 – 150.
7. Oleksenko V. Innovative Trend of Acquiring and Mastering Knowledge by Students // International Letters of Social and Humanistic Sciences. – Switzerland, 2015. – V. 65. – P. 88 – 95.
8. Oleksenko V. Technology of Mastering Educational Material in Universities // World Scientific News. – Poland, 2016. – V. 42. – P. 119 – 131.
9. Oleksenko V. Features of knowledge quality of university students in Ukraine // International Letters of Social and Humanistic Sciences. – Switzerland, 2017. – V. 76. – P. 36 – 42.
10. Oleksenko V. Modern Classes at Universities. In: Perspective directions of development of philology, linguistics and communication study : collective monograph. – Nelson, New Zeland, Aotearoa Publishing, 2018. – P. 4 – 18.
11. Олексенко В. М. Лінійна алгебра та аналітична геометрія : підруч. [для студ. вищ. техн. навч. закл.]. – Харків : НТУ «ХПІ», 2006. – 372 с.

#### References (transliterated)

1. Zakon Ukrainy «Pro Vyshhu osvitu» [On higher education]. *Golos Ukrainy* [Voice of Ukraine]. August, 6, 2014, no. 148 (5898), pp. 9–19.
2. Andrushhenko V. P. *Rozdumy pro osvitu : statyi, narysy, interv'yu* [Reflections on education: articles, essays, interviews]. Kyiv, Znannya Ukrainy Publ., 2005. 804 p.
3. Oleksenko V. M. Innovatsiyni pidkhody do vykladannya matematychnykh dystsyplin [Innovative approaches to teaching mathematical disciplines]. *Novi tekhnologiyi navchannya : nauk.-metod. zb.* [New teaching technologies : scientific and methodological digest]. Kyiv, NMC "Nemishaev" Publ., 2014, vol. 80, pp. 6–9.
4. Bashmakov M. I. My uchim i uchimsya matematike v nashem obshhem dome – Evrope [We teach and study mathematics in our common home – Europe]. *Matematika v shkole* [Mathematics at school]. 2002, no. 1, pp. 3–6.
5. Wikipedia. Problem solving. Available at : [https://en.wikipedia.org/wiki/Problem\\_solving](https://en.wikipedia.org/wiki/Problem_solving) (accessed : 5 October 2019).
6. Ovchar O. Metody rozv'yazuvannya prykladnykh zadach [Methods for solving applied problems]. *Molod' i rynek* [Youth and the market]. 2010, no. 10 (69), pp. 145–150.
7. Oleksenko V. Innovative Trend of Acquiring and Mastering Knowledge by Students. *International Letters of Social and Humanistic Sciences*. Switzerland, 2015, vol. 65, pp. 88–95.
8. Oleksenko V. Technology of Mastering Educational Material in Universities. *World Scientific News*. Poland, 2016, vol. 42, pp. 119–131.
9. Oleksenko V. Features of knowledge quality of university students in Ukraine. *International Letters of Social and Humanistic Sciences*. Switzerland, 2017, vol. 76, pp. 36–42.
10. Oleksenko V. Modern Classes at Universities. In : *Perspective directions of development of philology, linguistics and communication study : collective monograph*. Nelson, New Zeland, Aotearoa Publishing, 2018. pp. 4–18.
11. Oleksenko V. M. *Liniyna algebra ta analitychna geometriya : pidruch. [dlya stud. vysh. tekhn. navch. zakl.]*. [Linear algebra and analytical geometry : textbook [for students of higher technical educational institutions]. Kharkiv, NTU "KhPI" Publ., 2006. 372 p.

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