

# Mathematical Analysis. Basis: Nomotex E-course

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**Abstract.** The paper describes the peculiarities of the development of the digital course "Mathematical Analysis. 1st semester" in the digital learning system Nomotex (DLS "NOMOTEX") [1], developed at the Department of Computational Mathematics and Mathematical Physics, Bauman Moscow State Technical University. The features of innovative teaching methods using this course are also presented.

## 1 Introduction

For different areas of training and specialties, different mathematical courses with variable depth of content are required, which correspond to the competencies of university graduates. [2, 3, 4, 5, 6] The need for designing personalized courses occurs during training on individual trajectories. [7, 8, 9, 10, 11, 12]

## 2 The course "Mathematical analysis"

The course "Mathematical analysis", studied in the 1st semester of the 1st year, contains the following modules (blocks): "Elementary functions and limits", "Differential calculus of functions of one variable" and "Exam".

In accordance with the curriculum, a student can score 70 points for a semester in two modules, and 30 points for an exam. At the same time, DLS "NOMOTEX" allows one to develop courses in different volumes and with different breakdowns for different specialties. At the moment, the course of the 1st semester in Mathematical Analysis is compiled differently for engineering specialties and the specialty "Mathematics and Computer Science" due to the peculiarities of the curriculum: for the specialty "Mathematics and Computer Science" 1.5 times more hours are supposed for lectures than for engineering specialties.

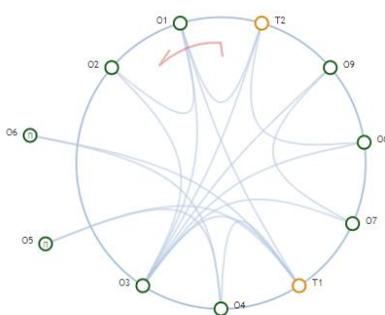
The discipline "Mathematical analysis" in the Knowledge Base is represented by the chapters "Elements of set theory", "Complex numbers and polynomials", "Functional dependence", "Sequence limit", "Limit of a function of one variable", "Continuity of a function of one variable", "Differentiability of functions", "Research of functions and construction of their graphs".

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Each of the paragraphs contains elementary statements (theorems, definitions, consequences, etc.), called Quanta of knowledge. Each quantum in the structure contains the so-called Links, i.e. for each quantum, one can clearly trace the statements that refer to it and for the study of which it is necessary to master the current quantum, and the quanta that need to be known to study the current one (Fig. 1).

### Function limit concept



**Fig. 1.** Structure of a paragraph with mapped relationships between quanta

The lecture course, traditionally taught in the discipline "Mathematical analysis", was significantly improved, and all the basic elements of the course were presented in accordance with the standard structure of quanta adopted in the DLS "NOMOTEX", which allows one to strictly systematize the premises, conditions and conclusions of a statement (Fig. 2) [1]:

### Limit of a function (definition by Cauchy) (0)

1. Definition and its connections

Consider the function  $f(x)$ .  
 Let this function be defined on some set  $X \subset \mathbb{R}$ , which has a limit point  $a$ , not necessarily belonging to this set  $X$ .

If for any number  $\varepsilon > 0$  there is such a number  $\delta > 0$ , generally speaking, depending on  $\varepsilon$  that for any  $\forall x \in X$ , belonging to the punctured  $\delta$ -surroundings  $\dot{U}_\delta(a)$  points  $a$ , function value  $f(x)$  belongs  $\varepsilon$ -neighborhood  $U_\varepsilon(b)$  numbers  $b$ ,

then the number  $b$  called the *limit of the function  $f(x)$  at  $x$ , aiming for  $a$* .

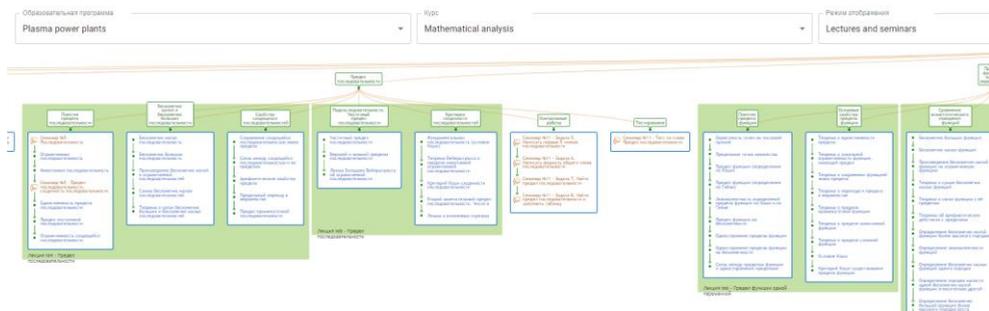
**Fig. 2.** The structure of a statement adopted in the DLS "NOMOTEX"

Each new quantum, with the exception of elementary concepts, refers to the previous ones, and hyperlinks are made in the text of the quantum, thanks to which students, when studying the material, have the opportunity not to look for the necessary concepts in lectures, but to follow the link, refresh their knowledge, and return to the current quantum being analyzed. This is especially true if the concepts used by the current statement were introduced in another paragraph, chapter or even subject, and could be forgotten by the student.

Of course, some engineering courses, due to the reduced number of hours and the structure of the approved curriculum, do not imply the study of all the material and all the quanta included in the discipline "Mathematical Analysis". Therefore, on the basis of the quanta of the discipline, courses of Mathematical Analysis for various specialties are formed, including only those chapters, paragraphs and quanta that are necessary for studying for this particular specialty.

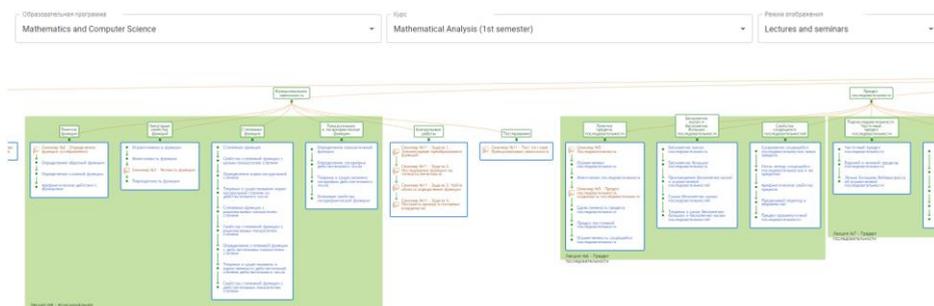
For this purpose, a separate functionality was created, called the Implementation of Neural Network Educational Programs, thanks to which it became possible to compile various course programs for specific specialties, taking into account the specifics of the specialty and the number of hours provided for lectures and seminars. Within the framework of the implemented functionality, it is possible to include or exclude individual chapters, paragraphs and quanta from the course, as well as to analyze individual quanta without proof.

The following structure of the course Mathematical analysis, for example, is offered for the specialty "Plasma power plants" (Fig. 3):



**Fig. 3.** The structure of the course "Mathematical analysis" for engineering specialties

The following structure is proposed for a more advanced curriculum of the course "Mathematical Analysis (1st semester)" for the specialty "Mathematics and Computer Science" (Fig. 4):



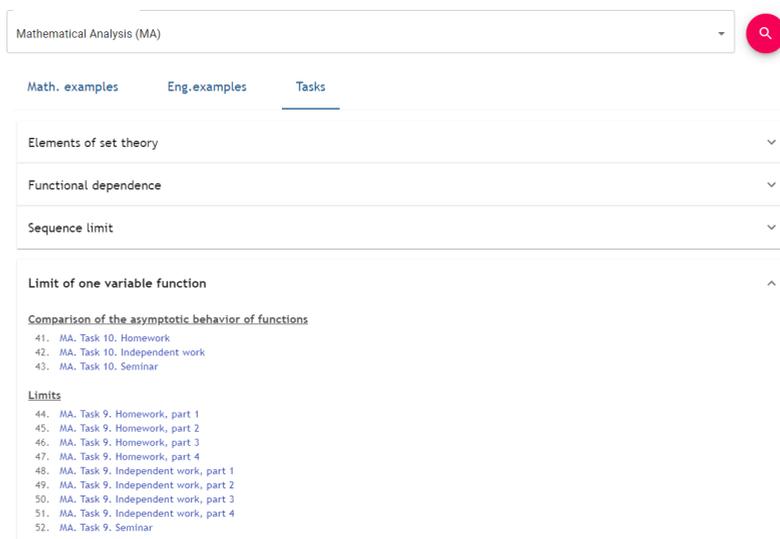
**Fig. 4.** The structure of the course "Mathematical analysis" for mathematical specialties

The tasks in the system are assumed to be typical, i.e. there are not separate tasks, but types of tasks: Seminar (problem solving algorithm and analyzed examples of problem solving), Independent work (IW), which the student performs either in the classroom or at home, Homework (HW), for which points are assigned in accordance with the point-rating system adopted at the university, Tests, available to students only during tests, and for which, similar to the type of HW, points are put down in accordance with the point-rating

system adopted at the university. At the same time, the types of tasks were written in accordance with the curriculum of the discipline, and covered the full volume of tasks that had to be completed during the semester.

An example of the names of problem types from the course "Mathematical analysis": "Calculating the limit of a sequence", "Finding monotonicity and extrema of a function", "Finding discontinuity points of a function and determining their type", "Finding the derivative of a given function", etc.

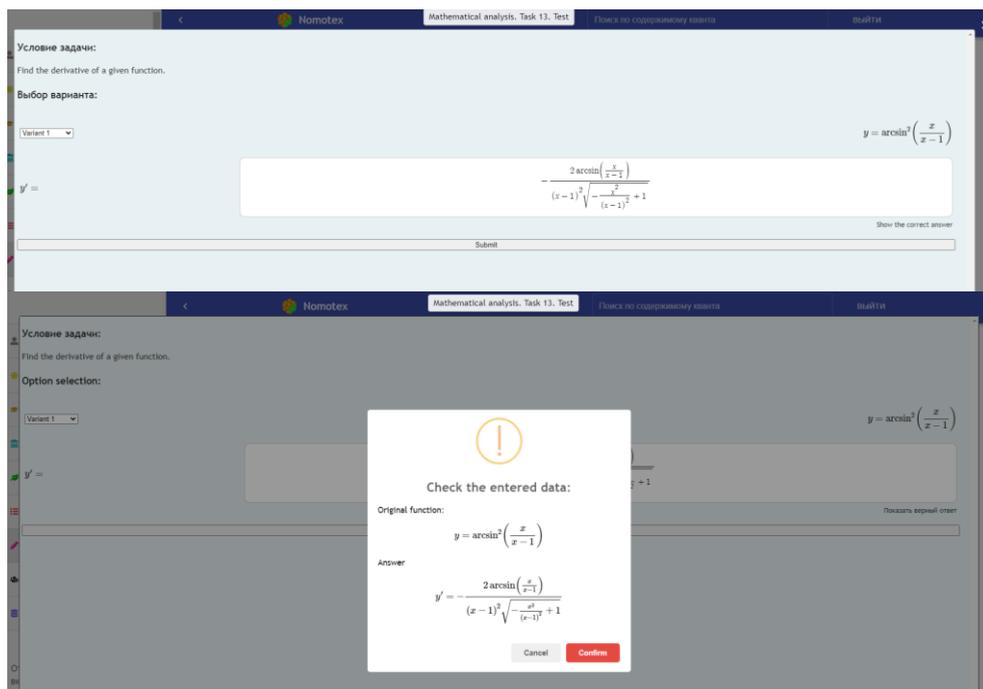
The types of problems correspond to the material covered in the theoretical lecture course, they can be accessed from the lecture quanta, as well as from the section "Visual Mathematics", where they are grouped by chapters and paragraphs of the lecture course (Fig. 5):



**Fig. 5.** Section "Visual Mathematics" in DLS "Nomotex".

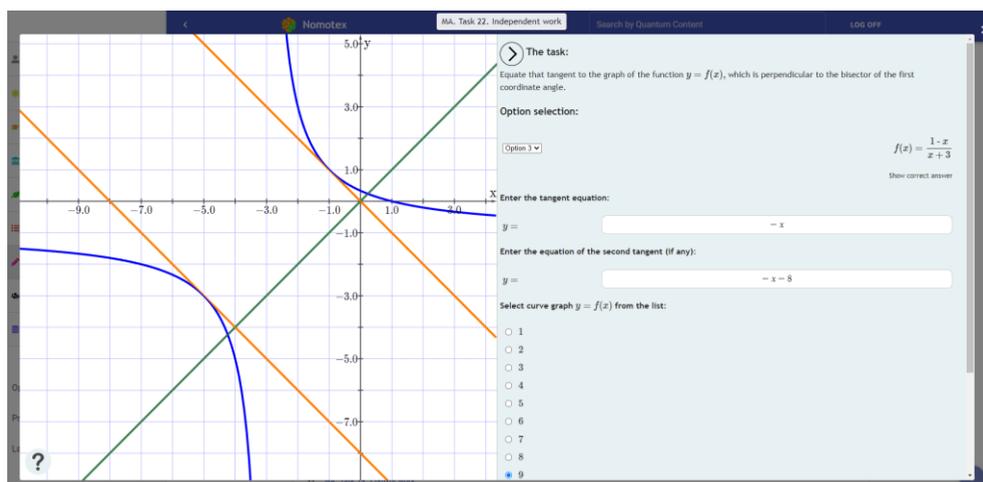
The number of problem types at the moment is 32, in each of them an algorithm for solving with all the formulas for the calculation was written, connected with the theory and references to all the necessary formulas, theorems and their derivation in theory, and the number of analyzed examples with a complete solution on average was about 5. Thus, students have access to more than 150 analyzed problems on the site with a fully explained solution. The average number of tasks for independent work (IW) for the course is 25 variants of selected tasks for each type, i.e. for training and checking the acquired knowledge, more than 800 variants of problems are available to students, the answer to which is saved on the site.

A student has the opportunity to enter answers to problems for independent solution (IW, HW, Test) in the system, while character-by-character input is available (numbers with irrationalities, functions of numbers, functions as an answer to the problem), while solving IW and HW the student can unlimited number of attempts to enter an answer, i.e. the student can make a mistake in the answer, double-check the solution, and enter the answer again. Each input of the answer is instantly checked, and the student receives a message about the correctness or incorrectness of his solution (Fig. 6):



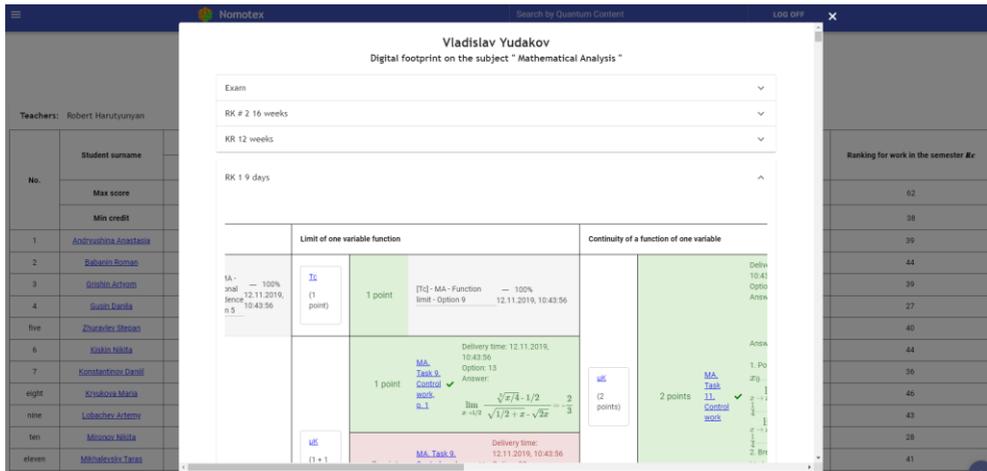
**Fig. 6.** Checking the solution in the DLS "Nomotex"

Some problems required a geometric solution, for example, a problem on the geometric meaning of the derivative. This was also implemented in the system (Fig. 7):



**Fig. 7.** Graphic problems in the DLS "Nomotex"

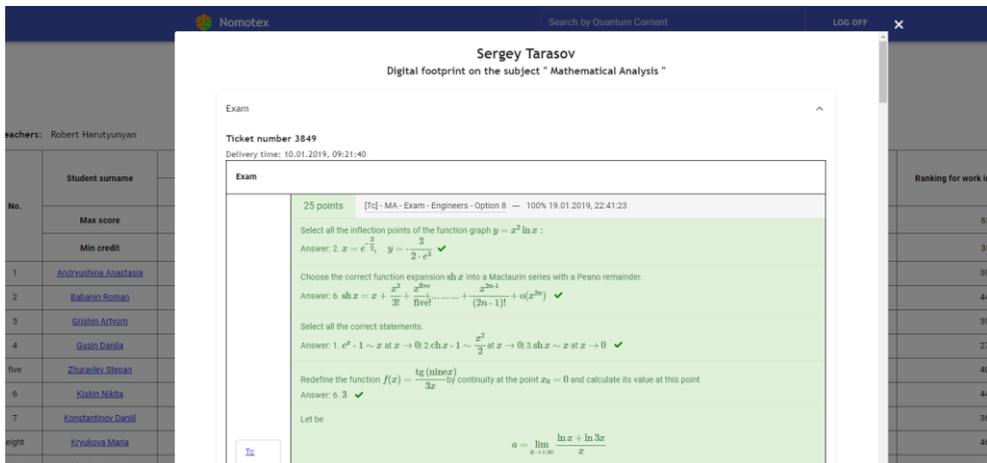
The issuance of tickets is automated within the DLS "NOMOTEX", and during the control events, each student in his personal account receives a ticket issued by the teacher. As the student solves the tasks from the ticket, points are put down automatically, and the student can immediately see whether the task has been completed correctly or not (Fig. 8):



**Fig. 8.** Ticket to the control event on Mathematical Analysis in the student's personal account in the DLS "Nomotex"

Points for a ticket are summed up automatically and are taken into account in the student's overall rating for the semester.

The exam is also held in the DLS "Nomotex", the traditional written form of the exam was replaced by a test, and additional points were awarded for the written-oral proof of the theorem to the examiner. The exam results were also displayed in the student's personal account, like tickets for control events (Fig. 9):



**Fig. 9.** The ticket for the exam in the student's personal account in the DLS "Nomotex"

### 3 Conclusions

Thus, the discipline "Mathematical Analysis", taught in the 1st semester of the 1st year, was fully implemented in the DLS "NOMOTEX", while the courses "Mathematical Analysis" and "Mathematical Analysis (1st semester)" were developed, read for engineering and mathematical specialties, respectively, and all statistics on the passage of milestone events by students trained in the system are saved.

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