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Problems and prospects of distance learning in teaching fundamental subjects to future Mathematics teachers

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Abstract. The research analyzes experience of implementing the courses *Mathematical Analysis* and *History of Mathematics* for future Mathematics teachers in the system of managing electronic academic courses (SMEAC) at Kryvyi Rih State Pedagogical University (KSPU). To create the courses, there is a block-modular approach enabling not only structuring the process of studying fundamental mathematical subjects in the distance form of training, but also controlling the rate and depth of students' mastering the material. There are examples of laboratory works on *Mathematical Analysis* performed by students independently in the computer mathematics system CoCalc.

1. Introduction

Distance learning started in the 18th century and has been demonstrating positive dynamics for the whole period improving its forms, methods, educational resources and the content-structural component. Since the emergence and development of the Internet and global informatization of society, distance learning and online teaching have been accentuated [13]. This has been caused by the worldwide situation in the current 2019/2020 academic year.

There are three keys, in our opinion, aspects of distance learning. First, this is a learning process, which means that it is characterized by the essential characteristics of the educational process (the two-sided nature of the process (teaching – learning), joint activities of subjects, a special systematic organization of the entire process, education and development of students in the learning process). Secondly, the remoteness of this process, that is, the implementation of training can occur at a distance between the subjects. And finally, interaction, which involves the implementation of systematic feedback between the teacher and the student. In the absence of at least one of the above aspects, talking about the implementation of distance learning, in our opinion, is not entirely correct.

Today, the complicated epidemiological situation makes students switch over to distance learning, this causing intensive development of the distance learning system (DLS). Thanks to the emerged mobile information and academic medium based on modern information technologies, the DLS enables emergence of an essentially new level of availability of education while preserving its quality under pandemic conditions [4].

Subjects of distance learning involve all the participants of the joint distance learning process irrespective of their location. This learning mode results in their obtaining and creating their own system of knowledge, skills and personal features.

The DLS is a systematic aggregate of data transmission tools, information resources, interaction protocols, software and hardware tools and those of managerial and methodological support aimed to

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satisfy users' academic needs. The system includes subjects directly or indirectly interacting in the academic process; the content determining the subject matter of their interaction; tools ensuring communication of a learner and a teacher who accomplishes renewed functions of management, correction and regulation [7].

The system is based on a structured set of goals, functions, tools, techniques, requirements and conditions of their effective interaction as well as factors influencing their efficiency.

Distance learning as a system of arranging a purposeful interaction of learners, teachers and learning tools can be presented as a set of three basic subsystems, each of them comprising certain components. The didactic subsystem is the primary and the basic one. It includes the components typical of traditional training – goals and the content of training, forms, methods, tools and principles of their implementation in the academic process. Yet, each of these components has its own specific features reflecting both their content and distribution of their roles and frequency of application to the academic process.

Their movement in the learner's mastering of knowledge and skills is accomplished in teacher-learner interaction through the training content and applied tools specific features of which change the character of teacher-learner interaction, their functions, the role, the place and the meaning in accomplishing the set goals [12].

It should be noted that application of distance learning to teaching fundamental subjects is efficient under the following conditions [12]:

- availability of the training and method basis in its full volume;
- expedient and competent combination of distance and contact forms of training;
- efficient control over quality of students' mastering the training material;
- an individual choice of training technologies by academic process participants.

Kryvyi Rih State Pedagogical University (KSPU) does its best to provide fulfillment of the mentioned conditions to the fullest extent. In order to improve efficiency of distance learning, students should master basic methods, ways and tools of data obtaining, storing and processing, skills of working on the computer as a means of managing information in the Internet and corporate information systems, which is finally determined as the data competence to be mastered.

Implementation of innovative information and communication technologies into the academic process enhances formation of a future Mathematics teacher's information competence.

The massive transition of all participants in the educational process to the format of distance learning undoubtedly indicates the need to study and generalize its results. First of all, the quality of assimilation of educational material by all students is important. The given paper is an attempt of systematizing experience of implementing the courses *Mathematical Analysis* and *History of Mathematics* into the system of managing electronic academic courses (SMEAC) at KSPU.

The suggested block-modular approach aims to develop and activate students' independent work through introducing Moodle as environment for electronic training, distance learning and testing [12]. Moodle aimed primarily at arranging teacher-student interaction is a center of creating learning materials and providing interaction of training participants [17].

For this reason, this article is aimed at studying problems and prospects of implementing the block-modular approach of distance learning into the process of teaching fundamental subjects to future Mathematics teachers.

2. Experience of implementing the course *Mathematical Analysis*

The fundamental subject *Mathematical Analysis* comprises six training courses:

- *Mathematical Analysis* 1;
- *Mathematical Analysis* 2;
- *Mathematical Analysis* 3;
- *Mathematical Analysis* 4 – figure 1 [3];
- *Mathematical Analysis* 5;
- *Mathematical Analysis* 6 [2].

Each of the courses corresponds to an academic term. Let us consider implementation of distance learning in the SMEAC at KSPU [9].

All these courses consist of three training modules. Each module is divided into thematic blocks containing theoretical materials with detailed examples of applying theory to solving practical tasks. Theoretical data are presented as PDF files, a block being a single file. They are based on the electronic training and method set developed by the Department of Mathematics and Methods of its Teaching at KSPU in the previous years.

Each module of the training course is finalized with self-training tests in a separate block and obligatory control tests on the training module materials. Self-training tests enable a student to evaluate the degree of knowledge mastering and, if necessary, eliminate gaps. Control tests are the same as test papers checked by University teachers manually. Test sheets containing too many mistakes are returned, while the teacher analyzes students’ mistakes and tells them which themes and issues are to be revised for them to get a positive mark.

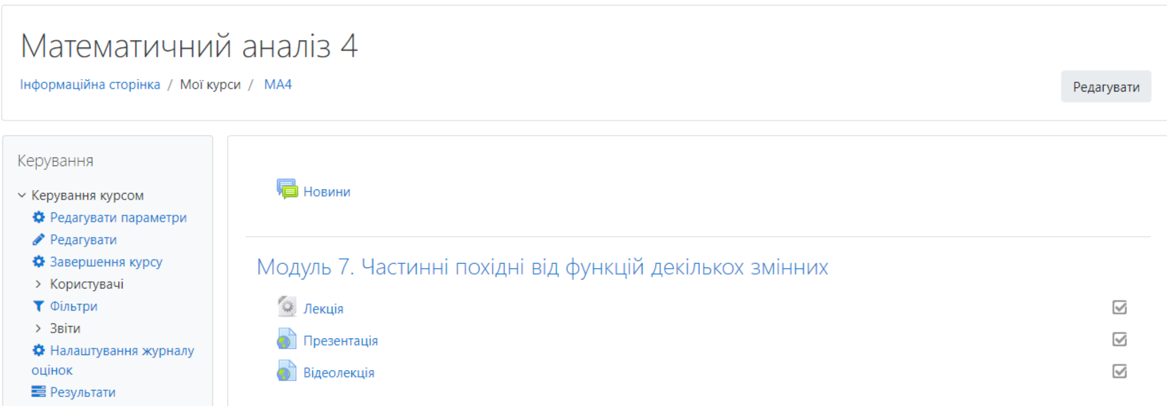

Figure 1. The fragment of the page with learning materials for the course *Mathematical Analysis* 4.

Each part of the course for both full-time and distance forms of training contains relevant test questions.

Test questions are of two types – offline tests assessed by the teacher and online tests assessed by the Moodle [10]. The number of questions per test can vary. Offline tests are a set of tasks (from 5 to 8) given entirely to a student without any answer options. The student is to send all solved tasks as a PDF file, a handwritten solution scanned being preferable. Solutions sent are assessed by the teacher.

Online tests are a form of traditional testing when tasks or questions are provided one by one to a student. There are either many answer options to select the right one (multiple choice) or just two options (True/False) or there is a space to enter the correct answer (number). There are no other task types provided like conformity or choosing a graphic answer on the current stage. Each task is assessed separately with the subsequent total score calculated [14].

Of course, offline tests are preferred as they are similar to ordinary tests used to assess students’ knowledge in the traditional form of training.

To obtain objective results of current testing in each test, testing parameters are adjusted, including:

1) time per attempt is limited depending on the complexity of a test (time is not limited by default);

2) the total number of attempts is set (i.e. the ordinary test envisages one attempt, the training test – three attempts);

3) a passing score is set;

4) the time interval between attempts is set (the authors set a two-day interval as the next attempt should be made after revision only);

5) the method of determining the final score between the assessed attempts is chosen (i.e. the best score or the average one).

As the Moodle possesses various options to process test results (assessment scales to be set, the mechanism of result revision when the teacher corrects test tasks after a student's attempt, tools to analyze testing results), there is an opportunity to analyze the quality of test questions from the viewpoint of their efficiency in knowledge assessment. Test results are presented in the score report containing final scores for all tests of the course. The report can be detailed for each student and also each of his/her attempts can be considered separately (the answer selected or entered, time of obtaining the question and time spent to obtain the answer).

Courses on *Mathematical Analysis* are focused on application of information technologies to the training process. There is a system of laboratory practicums with students using the computer mathematics system CoCalc applied to complicated projects being suitable to perform calculations [16]. CoCalc [14] provides students with templates to perform a laboratory work. Following the instructions in commentaries, students enter their input data and, after checking out, they analyze solutions. The course *Mathematical Analysis* 3 provides for the laboratory practicum developed by the authors with the following structure.

Laboratory work 1. "Calculation of a definite integral".

The example of a template:

```
integral(1 + x + x^2, x)
numerical_integral(1 + x + x^2, 0, 3)[0]
```

The result of the problem $\int(1+x+x^2)dx$ and $\int_0^3(1+x+x^2)dx$ is in figure 2.

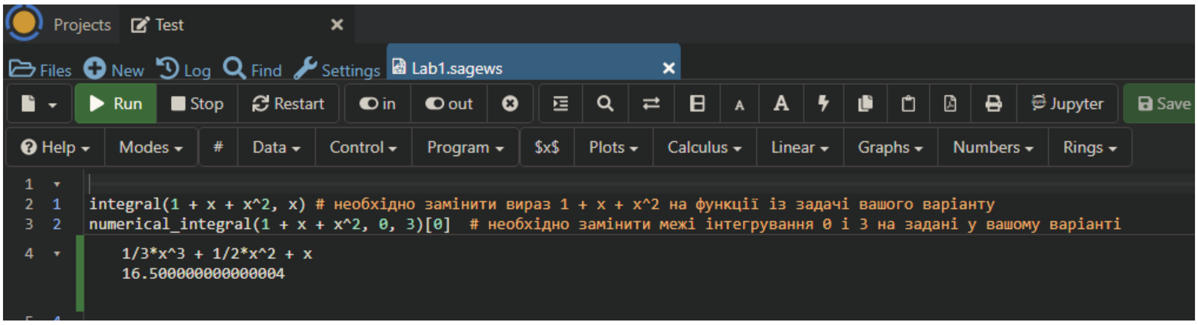

Figure 2. The fragment of the page with Laboratory work 1.

Laboratory work 2. "Calculation of a definite integral through integrating by parts".

The example of a template

```
integral(exp(x)*sin(x), x)
numerical_integral(exp(x)*sin(x), 0, 1)[0]
```

The result of the problem $\int e^x \sin(x)\,dx$ and $\int_0^1 e^x \sin(x)\,dx$ is in figure 3.

Laboratory work 3. "Integration of rational functions".

Laboratory work 4. "Integration of irrational functions".

Laboratory work 5. "Calculation of the plane curve arc length".

The example of a template

```
x = var('x')
parametric_plot((3*cos(x),sin(x)^3),(x,0,pi),rgbcolor=hue(0.6))
numerical_integral(sqrt(diff(3*cos(x),x)^2+diff(sin(x)^3,x)^2), 0,
       pi)[0]
```

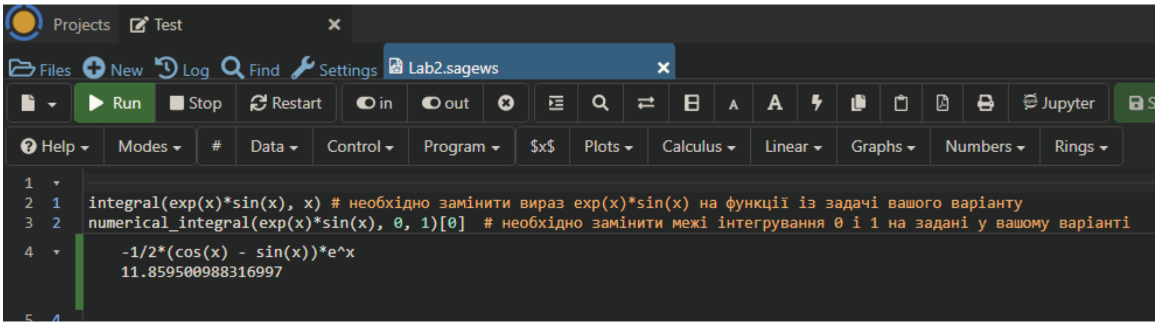

Figure 3. The fragment of the page with Laboratory work 2.

The result of the problem "Calculate curve length $\begin{cases} x(t) = 3\cos t, \\ y(t) = \sin^3 t; \end{cases} t \in [0, \pi]$" is in figure 4.

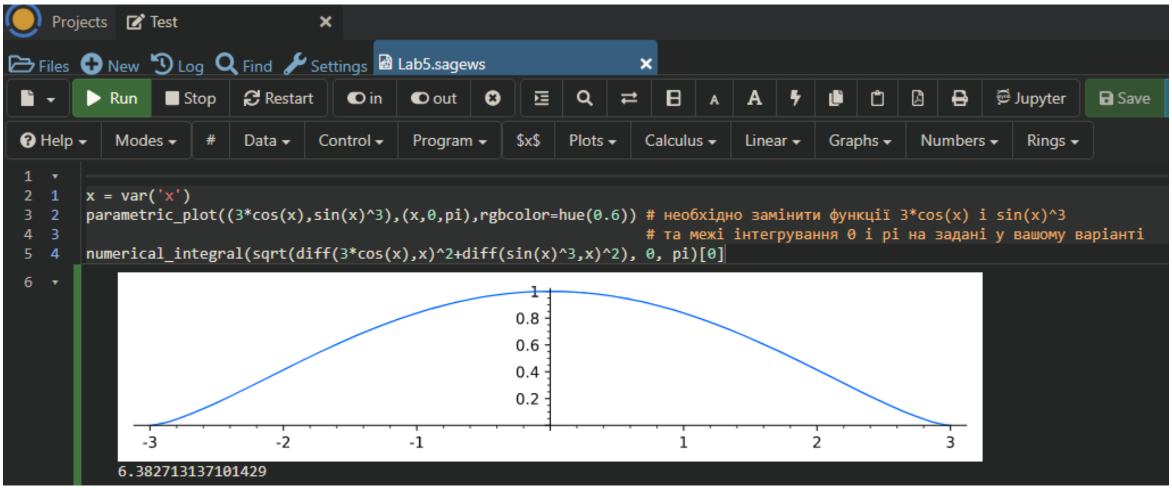

Figure 4. The fragment of the page with Laboratory work 5.

Laboratory work 6. Calculation of squares of plane figures".
The example of a template

```
plot(sin(x)^3,(0,pi))
numerical_integral(sin(x)^3, 0, pi)[0]
```

The result of the problem "Calculate area $y = 0, y = \sin^3 x$" is in figure 5.

Information technologies play an essential part in developing students' space-graphic culture. Particularly, the computer mathematics system CoCalc enables students to model 3D geometric objects and comprehend the role of information technologies in solving mathematical problems.

3. Experience of implementing the course *History of Mathematics*

Let us consider implementation of the course *History of Mathematics* in the SMEAC at KSPU [16]. Nowadays, it is impossible to imagine a Mathematics teacher's activity without studying history of this science.

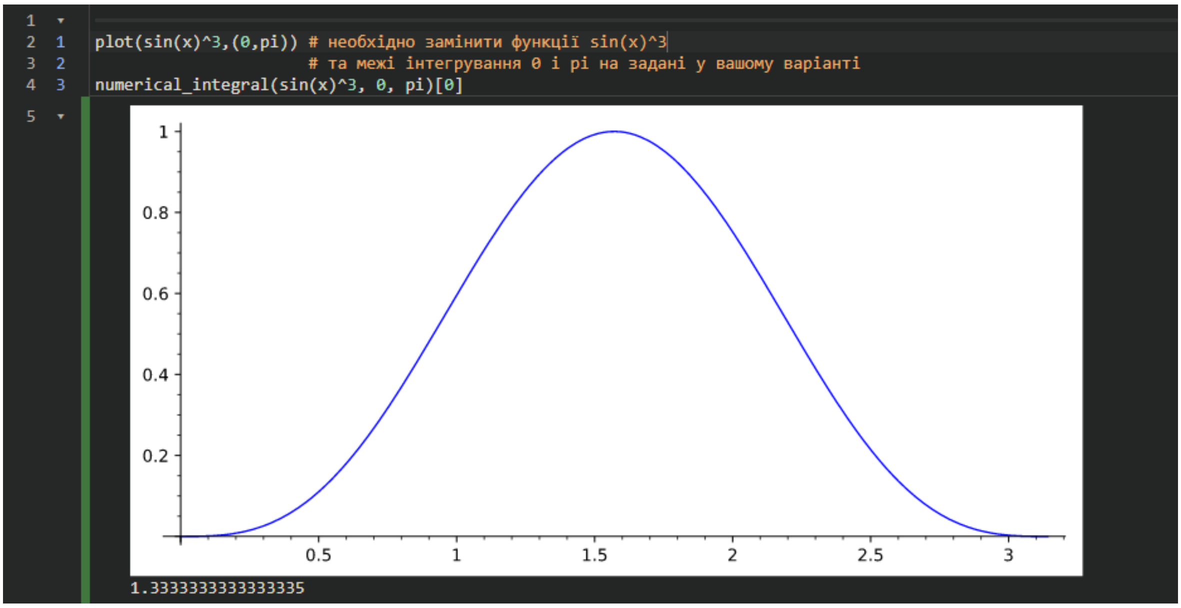

Figure 5. The fragment of the page with Laboratory work 6.

Currently, *History of Mathematics* as a historic subject is referred to humanities and applies not comparative but absolute categories (the time series "it was-it is-it will be", the spacious characteristics "here-there"), tends to use pure descriptions and discusses the past from the viewpoint of the present [6]. On the other hand, a number of modern mathematicians, while confirming the thesis of *History of Mathematics* as a historic science, compliment it with the idea that it is also a fundamental mathematical subject. "Now, its primary task is to define regularities of emergence and development of mathematical ideas. Naturally, with this respect, people with both specific mathematical training and experience of their independent scientific work can succeed in dealing with *History of Mathematics*" [5] (hereinafter the translation is ours).

Studying *History of Mathematics* enables distinguishing general principles of developing the mathematical science, determining external and internal factors of evolution of scientific theories. Any science evolves is constantly evolving. There is continuity of ideas as new scientific theories result from criticizing the previous ones. A lively talk in class is an essential component of the training process that is difficult to be implemented in distance learning.

Besides, application of elements of *History of Mathematics* to a secondary school course is efficient for forming schoolchildren's cognitive interest, this rising requirements to the level of professional training in this field of a future Mathematics teacher's activity. Therefore, creation of the distance course on *History of Mathematics* at a pedagogical higher educational institution is a priority from the professional viewpoint.

Nowadays, methodological problems are highlighted in teaching *History of Mathematics* at universities. There are some criteria of selecting the course content at a pedagogical higher educational institution [15]:

- methodological orientation;
- general cultural orientation;
- professional and pedagogical orientation;
- conformity of themes with syllabuses of mathematical subjects;
- minimization.

These criteria are used as the basis for creating the distance course *History of Mathematics* in the SMEAC of KSPU, conformity of themes of the course *History of Mathematics* with syllabuses of mathematical subjects being highlighted. The course content includes issues related to the history of development of basic sections of classical mathematics and elementary mathematics, which are part of subject training of students of Speciality *014 Secondary Education (Mathematics)*. Each mathematical course discloses to future school teachers a whole world of notions and results which should be perceived from the viewpoint of their emergence and development. This enables integration of fundamental mathematical subjects into the SMEAC of KSPU, which is to be implemented in the nearest future. *History of Mathematics* is presented as an integrating, systematizing subject taught after studying basic fundamental subjects. Students can compare Newton's "fluxions" theory and Leibnitz's theory of infinitesimal Mathematical Analysis, etc.

While creating the course, it was also important to consider the minimization criterion, which required thorough selection of the course content to achieve necessary minimum data due to time limitation accompanied by large notional load.

The content of the course *History of Mathematics* aims to form a future Mathematics teacher's competence, including:

- free operation of historical and mathematical facts, extension of historical and mathematical scope;
- mastering methodological knowledge on history of the science;
- the ability to apply historical and mathematical knowledge to new situations (pedagogical, method-related, training);
- the ability to design training content to teach students.

In the SMEAC of KSPU, the subject *History of Mathematics* consists of two training modules. Each module is divided into thematic blocks containing theoretical materials, presentations and seminar materials.

At the end of the course, there are five tests containing five tasks (two variants per test).

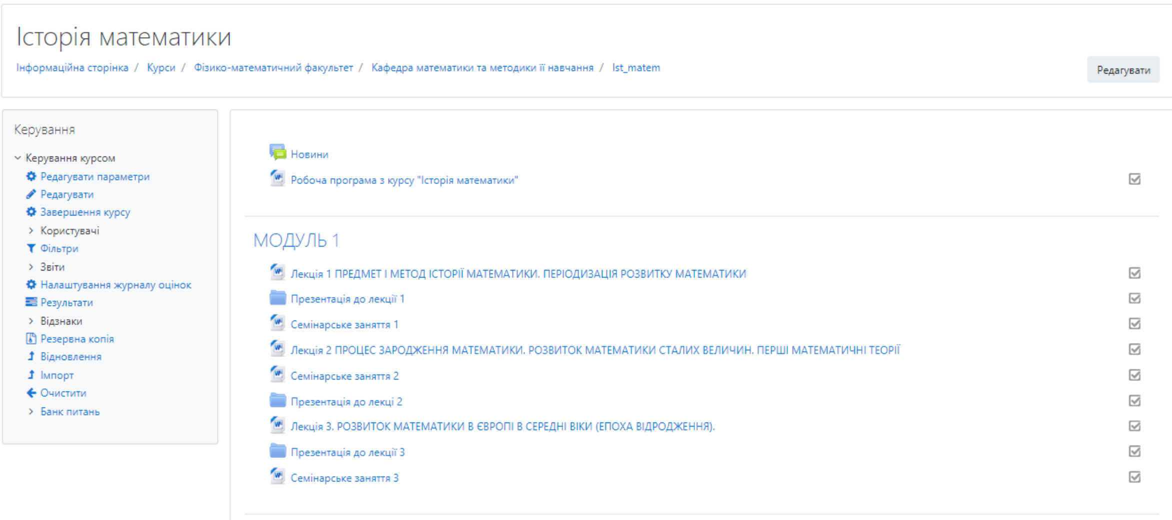

Figure 6. The fragment of the page with learning materials on the course *History of Mathematics*.

To obtain objective results of the current check of knowledge for each test, testing parameters are set:

1) time per attempt is limited (15 minutes by default);
2) the total number of attempts is set (one attempt);
3) the passing score is set.

4. Conclusion

The stated results are a partial generalization of the department's experience in ensuring the fundamental nature of the education of future Mathematics teachers. This approach is illustrated by the example of teaching *Mathematical Analysis* and *History of Mathematics*. The fundamental nature of education is effectively supported by the use of Moodle. Distance learning technologies for daytime education make it possible to study independently and organize a continuous learning process in accordance with the principles of open education. The Moodle LMS, thanks to its flexible technical capabilities, meets the requirements of the modern educational process. Distance learning technology for *Mathematical Analysis* and *History of Mathematics* on the Moodle helps to develop the competencies of students. The multimedia educational material, located on the Moodle, allows you to create more favorable conditions for improving the professional competencies of students, to improve their proficiency in various types of professional activities in this and related disciplines. The possibilities of the Moodle LMS as one of the tools are substantiated: for the development of the student, self-learning and self-development, for individualized modular training and collective solution of educational tasks, for the exchange of knowledge, for the process of monitoring the level of competence formation and regular reporting.

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