Organization of Independent Work of Students in LMS Moodle Using a Metacognitive Approach (on the Example of Physical and Mathematical Disciplines)

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Abstract. Recent years of the covid pandemic and military threats have significantly exacerbated the need for young people to obtain university education remotely. This also increases the requirements for the effectiveness of using the didactic capabilities of digital means and tools of distance education, and the quality of relevant content for organizing and supporting students' independent educational activities. Able to effective independent cognitive activity can only be a person who has the appropriate cognitive skills, and is aware of his own cognitive processes. Therefore, filling students' independent work with metacognitive content should be considered as the subject and purpose of training, along with the traditional goal of the university, which is the formation of subject knowledge and skills. The subject of our research is the use of means and tools of LMS Moodle for the organization of independent work of students based on a metacognitive approach in the study of physical and mathematical disciplines. The article analyzes the problems of organizing students' independent work and offers some ways to solve them using the Moodle functionality. Examples of the use of individual Moodle activities by the article's authors for the organization and support of independent work of students are given.

Keywords: LMS Moodle, E-learning Course, Independent Work, Metacognitive Approach, Physical and Mathematical Disciplines.

1 Introduction

The Reference Framework of competencies for democratic culture, developed by the Council of Europe's Department of Education, identifies a set of 20 competencies that educators should focus on to strengthen the capacity of learners to be competent and effective citizens of a democratic society. One of them is the ability to learn independently, which is necessary for a person “to pursue, organize and evaluate their own learning, following their own needs, in a self-directed and self-regulated manner, without being prompted by others” [1], because it is necessary to learn throughout life.

Therefore, the effective organization of independent students’ work is an important prerequisite for successful learning.

Thanks to the development of digital technology, Internet platforms have become an integral feature of the modern educational process. One such platform is LMS Moodle, which has a wide functionality for organizing independent work and is free, open-source and used by most universities. However, effective targeted (to form students' ability to self-learn) use of LMS Moodle requires not only knowledge of the platform's functionality and technical skills in using its tools but also a methodological approach to learning.

The proposed article considers the tools of LMS Moodle to organize and support the independent work of students in the study of physical and mathematical disciplines based on the metacognitive approach. The metacognitive approach is based on developing cognitive skills that allow students to learn and control their learning independently. It is the metacognitive approach to the organization of students' independent work that focuses on the formation of the ability to plan, control and evaluate their own learning.

The work aims to study the capabilities of LMS Moodle tools to support a metacognitive approach to the organization and guidance of students' independent work in studying physical and mathematical disciplines.

2 Literature Review

The use of digital technologies for the organization of independent work of students in the study of physical and mathematical disciplines is the subject of research by many scientists, for example [2, 3]. Here are some results of scientific research on the problem of organizing independent work of students in the digital age. The study [4] analysed the experience of Finland in organizing independent work of students, in particular, the influence of the level of digital competence of students on the quality of education is revealed.

The study [5] of emphasized the need to implement self-managed learning, that is, the participation of students themselves in determining the purpose of training, planning, presenting, and evaluating their work, etc. Various problems of training organisations through LMS Moodle became the subject of scientists' research [6]. The study [7] aims to specify, in a practical way, procedures and automation guidelines in Moodle based on the experience of instructional design; and the structuring of online activities through the programming of automated flows by configuring conditional rules and the integration of a virtual assistant to attend general queries with a Chatbot tool named Dialogflow from Google.

Opportunities and examples of using metacognitive learning strategies, and self-studying students in mathematics, are disclosed in [8, 9]. In particular, metacognitive activity is interpreted as a complex integrative formation aimed at controlling the processes of perception, storage, processing, and reproduction of information. So, the study [10] shows, how metacognitive strategies for teaching mathematics can improve students' metacognition, as well as how students and teachers of mathematics can use metacognitive strategies. In [11] the problems of increasing the motivation and self-awareness of students in the process of learning mathematics are investigated. To do this, it is proposed to use a metacognitive approach to learning. The tools of LMS Moodle were chosen to implement the research tasks.

Despite numerous scientific studies on the problems of organizing independent work of students, using means of LMS Moodle as one of the most common systems of distance learning, the organization of this work in the process of studying physical and mathematical disciplines based on a metacognitive approach has not yet been the subject of special scientific research. The capabilities of LMS Moodle to implement this task have not been sufficiently studied.

3 Research Methods

The research was carried out within the framework of the complex scientific theme of the Department of Mathematics and Physics of Borys Grinchenko Kyiv University "Mathematical methods and digital technologies in education, science, technology", DR No 0121U111924. The following research methods were used in the work: analysis, generalization of scientific literature to reveal the essence of the metacognitive approach; systematization of LMS Moodle tools for organizing independent work in physical and mathematical disciplines; empirical (questionnaires) to identify problems in the organization of independent work of students, observational (pedagogical observation, reflection of research activities) to implement independent work of students based on the metacognitive approach in LMS Moodle.

4 Research Results

4.1 Survey results and problem statement

To identify the problems associated with the organization and implementation of independent work of students in the process of teaching physical and mathematical disciplines, as well as to clarify the attitude of teachers and students toward the role and place of independent work at the university, during March 2023, we conducted a survey. Respondents were 150 students who study or previously studied physical and mathematical disciplines. In addition, we interviewed 129 teachers from Borys Grinchenko Kyiv University and other universities in Ukraine.

The survey results showed the following.

Among the significant factors that negatively affect the implementation of independent work of students, teachers name the following: the reluctance of students to work independently and the teacher's lack of leverage in this situation – 59.1%; lack of methodological literature for teachers on the organization and management of students' independent work, control and evaluation of its results – 46.7%; lack of proper motivation of the teacher for this type of activity (management of most of the independent work of students is not taken into account in the teacher's educational load) – 46.7%. Students, on the other hand, see the problem mainly in their own insufficient metacognitive competencies: they do not know where to start solving a problem or working out a theory – 45.3%; they do not know how to overcome difficulties when they come across them when working out a theory or solving a problem – 39.3%; they have insufficient organizational skills (ability to plan and distribute time between different types of work) – 36.7%.

When asked about the use of the metacognitive approach in the organization of student's independent work, only 13.4% of teachers answered that they organize student's independent work based on this approach, and 19.5% (every fifth) chose the answer: "I do not know what it is."

This indicates the need to improve the methodological support of students' independent work, both on self-study issues (for students) and pedagogical guidance of students' independent work. It also confirms the relevance of unlocking the possibilities of a metacognitive approach to learning aimed at developing students' ability to learn and, in the conditions of distance learning - the importance of digital support for students' independent work and pedagogical guidance.

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4.2 LMS Moodle tools for organizing students' independent work in physical and mathematical disciplines

Analysis of the literature on the problems of organizing independent cognitive activity of students and our own experience give grounds to assert that the metacognitive approach in the educational process in general, in particular, and in the organization and management of independent work of subjects of learning, creates the conditions necessary for their effective self-development and the realization of individual creative potential, and the use of the capabilities of the LMS Moodle functionality helps to implement this approach more successfully.

The metacognitive approach to organizing students' independent work involves: teaching students metacognitive learning strategies to understand, control and regulate their cognitive activity; planning learning activities so that students can gradually take more responsibility for their learning; using active teaching methods and interactive platforms to engage students in the construction of their knowledge, rather than passively obtaining them; providing feedback to students on their use of metacognitive strategies; encouraging students to reflect on their learning experience; educating and developing students' ability to analyse the dynamics of their metacognitive skills, encouraging them to view errors as opportunities for learning.

The specificity of physical and mathematical disciplines (for example, the logic and interconnectedness and interdependence of various topics, a high level of abstraction - in mathematics, mathematical modelling of complex systems - in physics) dictates the need to have specific metacognitive strategies for successful learning. These are, in particular, conceptual understanding, not formal memorization, prediction of the result (hypothesis) and search for ways to prove or refute, not passive familiarization with the result, verification of the solution, and not a simple statement of the answer, search for alternatives and analogies, etc. Some metacognitive self-learning strategies (for the student) and learning (for the teacher) and possible Moodle digital tools to support these strategies are shown in Table 1.

Table 1. Moodle LMS tools for organizing independent work in physical and mathematical disciplines

Competencies of students for self-study (*learning*)	**Pedagogical metacognitive strategies**	**Moodle Tools**
Ability to plan and distribute time between different types of work	Planning training	Checklist
Ability to determine (or anticipate) goals and ways to achieve them	Familiarization with the expected learning outcomes before studying the topic	Assignments (with “Know-Want to know-Learned” table), Choice
Analytical skills: analysis; ability to generate "correct" questions; awareness of difficulties and obstacles; monitoring the level of the material understanding; critical evaluation of the result obtained; search, consideration of alternative solutions, analysis of advantages, and disadvantages; logical thinking; ability to use mathematical tools	Active teaching methods that encourage the search and construction of knowledge. Formative assessment. Ensuring the ability to build an individual educational trajectory, adaptive learning with the ability for everyone to receive assistance as needed	Lesson, Assignments, Quiz, Forum, Chat, Workshop, Wiki, Glossary, External tool, H5P
Communication skills: the ability to explain and argue their actions; the ability to seek (if necessary) help; the ability to use mathematical language	Joint training in groups, couples. Execution of projects.	Wiki, Glossary, Forum, Workshop, Chat, Database, External tool
Motivation	Implementation of practically oriented tasks, mathematical modelling	Assignments, Choice, Forum, External tool
Ability to read (study) mathematical literature, find the right sources	Formation of this ability through special tasks, relevant content, as well as “instructional memos” to support active reading	Lesson, Assignments, Quiz
Ability to self-assessment: the ability to assess their progress; the ability to adjust, if necessary, their educational trajectory	A questionnaire, survey, reflection; Formative assessment	Lesson, Quiz, Feedback, Choice, Workshop

Example 1. ***Assignments.*** Activities “Assignments” we use in project-based training. For example, to carry out research projects with small groups of students, you can build an external resource that allows participants to work together. The teacher creates an online service Miro Online Writeboard and embeds it into the activity of the Task (HTML tool “iframe”).

Gives an example (see Fig. 1) of students performing research in the discipline of "Physics". After analysing the laws of horizontal motion (axis OX), the study's main task was to write down the laws of vertical motion (axis OY). It was important that this tool is needed to provide a common workspace for collective research work.

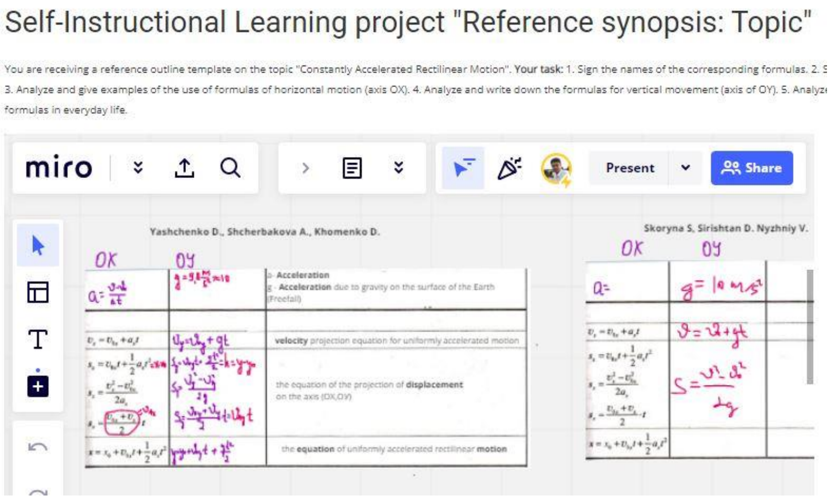


Fig. 1. Activities Assignments with built-in Miro Online Writeboard for small group projects

Example 2. ***Lesson.*** The activity “Lecture” can and should be used not just for placing certain theoretical material, but for organizing adaptive self-educational activity, with different trajectories, transactions between pages, various additional clusters, pages with test questions or tasks (for automatic verification) after logically completed fragments of text, the answers to which would indicate an understanding of what was read and, accordingly, the possibility (or impossibility) to go further. In addition, for a virtual lecture to compensate for the lack of “live” communication between the teacher and students, there must be a special organization of content and a special style of presentation that models metacognitive behavior. All material should be divided into small logically complete blocks, and the presentation of the material (proof of the theorem, for example) should take place in the form of an imaginary dialogue (the author / lecturer asks a question and answers himself), so that the student has the feeling that he is thinking out loud. For more information about the virtual lecture, see [12].

Example 3. ***Forum.*** For an independent solution of the first-year students-mathematicians were offered 32 planimetric problems, which had a non-standard and unusual, yesterday's secondary school students, the formulation of the condition. This confused the students. Most, having read the conditions and not seeing the obvious (usual) algorithm of actions to obtain the result, simply gave up. And one wrote: “How can you solve such problems if almost nothing is known? I don't even know where to start.”

An example of how a teacher took advantage of the situation to develop students' thinking and metacognition is given below.

At the Forum "Strong planimetric nuts" of the e-learning course at Moodle, the teacher fits the condition of one of the 32 tasks – "What is the square area?" (see Fig. 2.a) and invites students to: a) ask questions to “discover” more data (which are “hidden”); b) offer a solution.

The metacognitive strategy of the teacher was to educate observation, learn to ask the right questions, and use the Forum tool to motivate students to solve the problem, creating an atmosphere of excitement and competition (see Fig. 2 b).

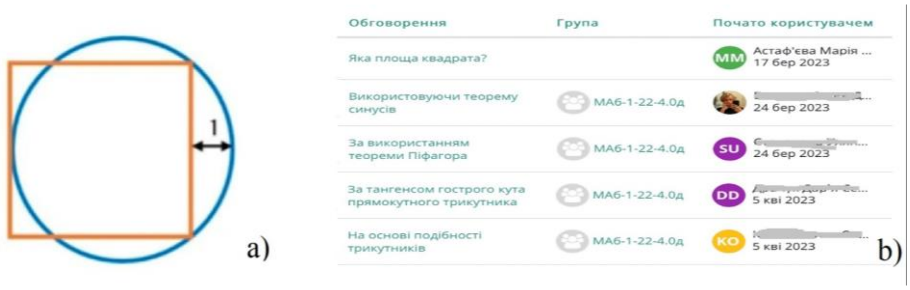
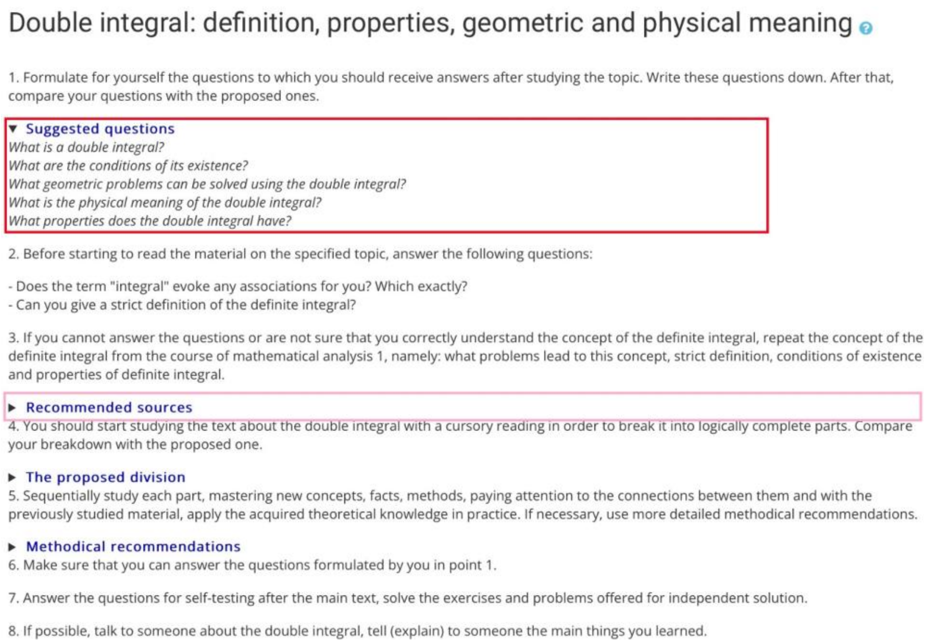


Fig. 2.a) images to the tasks; b) discussion of solution in the forum

As a result, the problem was solved in seven different ways. When posting his solution on the Forum, the student had to fill in the required field "Theme" (left column), which obliged him to briefly (in one phrase) indicate the method or key idea of the solution, for example, "Using the cosine theorem" (one of the important cognitive abilities for self-learning!). And, finally, the teacher initiates reflection (students discussed the proposed solutions, reflected on their thinking, described, and analysed the search for the idea of a solution, evaluated their own cognitive experience). Here is one of the posts, which shows that its author is aware of his metacognitive strategy (to perform additional constructions to see the idea) and evaluates it as effective:
“At first glance, it seemed that the problem could not be solved, because insufficient information was given. But, considering various variants of additions, a rectangular triangle immediately struck me, from which, according to the Pythagorean theorem, it is easy to find the side of the square.”

Example 4. ***Hidden text.*** To provide an individual approach in guiding the independent work of students, there is often a need to initially hide from students a part of the text on the page of the educational material, with the possibility of access to it if necessary. Moodle allows you to do this in HTML code editing mode. Hidden text can be the solution to the problem, hints (the idea of proof, the stages of solution), more detailed explanations of individual fragments, etc. Below (See Fig. 3) an example of Metacognitive Scaffolding to the task of working independently (according to the textbook) on the topic: “Double integral: definition, properties, geometric and physical content" (in the e-learning course of the academic discipline "Mathematical Analysis") is given.



Double integral: definition, properties, geometric and physical meaning

1. Formulate for yourself the questions to which you should receive answers after studying the topic. Write these questions down. After that, compare your questions with the proposed ones.

▼ Suggested questions
What is a double integral?
What are the conditions of its existence?
What geometric problems can be solved using the double integral?
What is the physical meaning of the double integral?
What properties does the double integral have?

2. Before starting to read the material on the specified topic, answer the following questions:

- Does the term "integral" evoke any associations for you? Which exactly?
- Can you give a strict definition of the definite integral?

3. If you cannot answer the questions or are not sure that you correctly understand the concept of the definite integral, repeat the concept of the definite integral from the course of mathematical analysis 1, namely: what problems lead to this concept, strict definition, conditions of existence and properties of definite integral.

▶ Recommended sources
4. You should start studying the text about the double integral with a cursory reading in order to break it into logically complete parts. Compare your breakdown with the proposed one.

▶ The proposed division
5. Sequentially study each part, mastering new concepts, facts, methods, paying attention to the connections between them and with the previously studied material, apply the acquired theoretical knowledge in practice. If necessary, use more detailed methodical recommendations.

▶ Methodical recommendations
6. Make sure that you can answer the questions formulated by you in point 1.

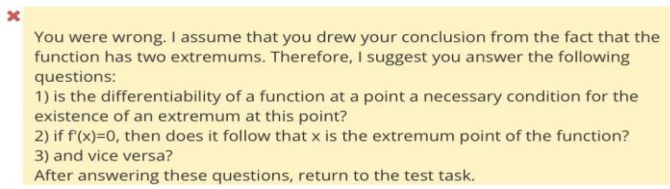
7. Answer the questions for self-testing after the main text, solve the exercises and problems offered for independent solution.

8. If possible, talk to someone about the double integral, tell (explain) to someone the main things you learned.

Fig. 3. An example of "hidden text" in the guidelines for reading a book text of mathematics

Example 5. ***Quiz.*** We avoid test tasks of the closed type when you need to choose one (correct) answer from several of the above because such tasks are useless for forming of conceptual knowledge and metacognitions. In addition, in tests for self-checking, we usually use the interactive mode of multiple attempts. For this, it is advisable to program errors.

Forming such a task, it is provided, in addition to the correct answer, several wrong ones that the student will give under the condition of certain (quite specific!) gaps in knowledge. Therefore, for each such incorrect answer, a comment is provided, aimed at making the student realize his mistake and independently come to the right conclusion. An example of such a comment on an incorrect answer is given in (see Fig. 4).



You were wrong. I assume that you drew your conclusion from the fact that the function has two extremums. Therefore, I suggest you answer the following questions:
1) is the differentiability of a function at a point a necessary condition for the existence of an extremum at this point?
2) if f'(x)=0, then does it follow that x is the extremum point of the function?
3) and vice versa?
After answering these questions, return to the test task.

Fig. 4. Corrective comment of the teacher in the test

After another attempt, there may again be a “corrective” comment on the wrong answer. The test in Moodle can be configured so that the student indicates how confident he is in the correctness of his answer. The use of this mode teaches students to an objective self-assessment and encourages them to solve the problem, analyse and check the solution, and not just send an immediate response.

Example 6. ***Wiki.*** The Wiki tool has wide opportunities for organizing students' independent work based on the metacognitive approach. Its functionality allows you to create collective pages that can be edited and commented on by users with access to these pages (the level of access is configured by the teacher). Moreover, the editing history is saved (unlike the Glossary tool). We use Wiki for students to perform collective projects (for example, create so-called conceptual tables on a certain topic [13]), as well as perform certain temporary roles: teacher, expert, and opponent. According to the history of editing, the teacher can “unobtrusively” track the evolution of each student's understanding of certain mathematical concepts, the dynamics of his metacognitive skills and make the necessary adjustments, as well as assess the knowledge and skills of students using the method of formative assessment. Here is an example of a task in the discipline “Mathematical Analysis 2”, implemented by the Wiki tool.

Task: "Be in the role of a teacher"

The student gave the following definition of the limit of the sequence of points of the metric space: "Point a is the limit of the sequence of points of the metric space, if the members of this sequence approach point a as their ordinal number increases." Determine what the student misunderstands and offer your way to eliminate his gaps in understanding the specified concept.

5 Conclusion

1. As a result of a survey of teachers and students, it was established that the difficulties in organizing and implementing independent work of students are due, firstly, to the insufficient level of methodological support. In addition, the low efficiency of students' independent work is explained, among other things, by the inability to self-learn.
2. Based on the analysis of the scientific literature, the potential of the metacognitive approach for organizing students' independent work is revealed (using metacognitive learning strategies to understand, control and regulate cognitive activity; encouraging students to take responsibility for their learning; using active teaching methods and interactive platforms to involve students in the construction of their knowledge; providing feedback to students on their use of metacognitive strategies; encouraging students to reflect on their learning experience).
3. The most important competencies of students for self-study are highlighted, the corresponding pedagogical metacognitive strategies for the implementation of independent work of students are given. The Moodle LMS tools to support these strategies are offered. Examples illustrate the possibilities of LMS Moodle for organizing students' independent work using a metacognitive approach.
4. It is shown that using Moodle as a learning support tool allows creating an interactive and dynamic learning environment where students can actively learn, acquiring and improving metacognitive competencies. In particular, the fragmentary results of the

study testify to the growth of students' self-regulatory competencies, namely, awareness of their metacognitive strategy and assessment of its effectiveness.

5. Analysis of the effectiveness of using Moodle tools for the organization of independent work of students in order to ensure a more active and aware of their learning activity, will be the subject of our further research.

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