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DIDACTIC POSSIBILITIES OF ORGANIZING MEDICAL CHEMISTRY LABORATORY CLASSES AS A CONTINUOUS LEARNING CYCLE USING ARTIFICIAL INTELLIGENCE TOOLS

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Abstract. The thesis analyzes the current state of medical chemistry laboratory classes in medical higher education institutions and reveals the didactic possibilities of consistently supporting the class with artificial intelligence tools across the stages of "pre-laboratory preparation – laboratory performance – post-laboratory reflection – adaptive assessment". These possibilities are illustrated by a clinical case developed for the laboratory work "Buffer Solutions and Buffer Capacity".

Keywords: medical chemistry, laboratory class, artificial intelligence, didactic possibility, clinical case, buffer systems, adaptive assessment, reflection.

In medical education, virtual laboratories, simulation technologies and artificial intelligence (AI) tools are being actively used in teaching fundamental disciplines as a means of extending the possibilities of the traditional laboratory. T. de Jong, M. Linn and Z. Zacharia showed that the combined use of physical and virtual laboratories yields the best results [1], while G. Makransky and co-authors found that using virtual simulations as a means of preparing for the real laboratory increased students' laboratory skills and self-efficacy [2]. However, these studies mainly examine the effect of an individual tool; a holistic approach covering all stages of the laboratory class and adapted to the specifics of medical education has not been sufficiently developed.

An analysis of the curriculum, laboratory manuals and the results of class observations revealed four features of the current situation: laboratory works are performed identically by all students on the basis of a single standard instruction;

clinical content is provided not at the level of the task, but only as a brief comment in the theoretical part; preparation for the class is limited to reading the textbook, and its quality is not systematically checked; reports are oriented toward recording rather than analysis and reflection. At the same time, an analysis of the content of the laboratory works showed that each work can be linked to a specific clinical process: solution concentration – with infusion solutions and drug dosage; titrimetric analysis – with gastric juice acidity; buffer solutions – with acidosis and alkalosis; colligative properties – with hemolysis and edema; complex compounds – with hemoglobin and chelation therapy.

Each of the identified features represents a specific methodological problem that can be solved with the help of AI tools. These possibilities manifest themselves across the stages of the laboratory class as follows (Table 1).

Table 1. Didactic possibilities of AI tools at the stages of the laboratory class

Class stage	Problem to be solved	Possibilities of AI tools
Pre-laboratory preparation	Coming unprepared; excessive cognitive load	Virtual experiment; question-and-answer with an AI assistant; adaptive entry test; interactive mastery of safety rules
Laboratory performance	Lack of individual support; reproductive performance	Checking calculations; guiding questions for interpreting observations; information for the teacher on students' progress
Post-laboratory reflection	Formal report; weak clinical relevance	Comparing the result with the theoretical value; analyzing the causes of errors; clinical situational tasks
Adaptive assessment	Uniform assessment; absence of an individual trajectory	Adaptive tests; analysis of individual errors; personal recommendations for the next class

Thus, AI tools make it possible to organize the laboratory class not as a single 80-minute lesson, but as a continuous learning cycle that begins before the class and

continues after it. This corresponds to D. Kolb's experiential learning cycle: virtual preparation and the real experiment provide "concrete experience", the analysis of results provides "reflective observation", clinical interpretation provides "abstract conceptualization", and individual recommendations provide the "active experimentation" stage [3].

To demonstrate these possibilities with a concrete example, the clinical case "Buffer Systems and Metabolic Acidosis" was developed for the laboratory work "Buffer Solutions and Buffer Capacity". The case describes a patient with type 1 diabetes mellitus who did not take insulin, whose blood pH dropped to 7.15, with decreased bicarbonate and deep, rapid breathing. Students analyze the binding of hydrogen ions produced by ketone acids to bicarbonate on the basis of the Henderson–Hasselbalch equation ($pH = pK_a + \lg([HCO_3^-]/[H_2CO_3])$, $pK_a = 6.1$), while in the laboratory they add hydrochloric acid to an acetate buffer solution step by step, measure the change in pH, calculate the buffer capacity and compare the result with the patient's condition.

In the case, AI tools perform a specific function at each stage. At the preparation stage, the student performs a virtual titration, and the AI assistant, rather than giving ready-made answers, asks guiding questions such as "Which particle binds hydrogen ions when an acid is added to a mixture of a weak acid and its salt?". At the performance stage, the AI checks the calculations and indicates the type of error (incorrect calculation of the logarithm, inverting the ratio of concentrations). At the reflection stage, the AI identifies logical gaps in the student's answer, and at the adaptive assessment stage it recommends individual exercises based on the errors made. The final grade and the correctness of the clinical interpretation are always confirmed by the teacher.

Based on the theoretical analysis and the case example, six didactic possibilities of AI tools in medical chemistry laboratory classes were identified:

preparatory – ensures that the student comes to the laboratory theoretically and technically prepared, reducing cognitive load;

visualization – makes the invisible submicroscopic level of chemical processes understandable;

individualization – provides each student with support and tasks matched to their level and errors;

professional orientation – individually generates tasks that link laboratory work to clinical situations;

reflective-evaluative – ensures error analysis and the formation of a personal learning trajectory;

organizational – frees the teacher from routine tasks, leaving more time for direct work with students.

To evaluate the effectiveness of the classes, it is proposed to measure students' experimental competence according to four criteria – motivational, cognitive, practical-experimental and reflective – on a 10-point scale (0–4 – low, 5–7 – medium, 8–10 – high level).

Conclusion. AI tools have broad didactic possibilities for eliminating the shortcomings of the traditional form of medical chemistry laboratory classes – the single standard instruction, uncontrolled preparation, weak clinical relevance and the formal nature of reports. However, these possibilities are not realized by themselves, but only within a holistic methodology that covers the four stages of the class, links the content of laboratory works to clinical situations, selects AI tools according to well-grounded didactic criteria and preserves the teacher's control.

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