Lights and shadows of teaching and studying biochemistry

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Received 15.04.2024 *Accepted 22.05.2024*

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Summary

The didactic process is well described by various models and approaches in the fields of pedagogy and psychology and current research include the influence of media and educational tools that affect the way knowledge is absorbed and the interaction between teachers and students, but also between students themselves. Integrating the neuroscience of the brain in the learning process allows us to better understand how the brain processes and remembers information and helps develop more effective teaching strategies. Teachers can use such principles to design lessons and teaching materials that stimulate the relevant areas of the brain and promote memorization. The teaching process evolves over time, which is why professional preparation of teachers is necessary. The effectiveness of teaching also depends on the motivation of students and their willingness to work systematically. Moreover, the challenges faced by teachers require the use of available tools to improve the teaching process. It is important to select teaching tools that are appropriate to both the specifics of the subject and the level of student engagement. The review describes the available innovative teaching methods and the authors' own experience in using a flipped classroom, blended learning, quizzes, virtual cases and tutoring in teaching basic subjects to veterinary students, as well as organizing competitions for ideal teaching tools.

Keywords: innovative didactics, virtual cases, Jigsaw, veterinary chemistry, veterinary biochemistry

Didactics is a bilateral process – the engagement of students is equally important as the involvement of teachers. It will be successful only when both sides are engaged and when expectations from both sides are clearly expressed and defined (34).

The specificity of veterinary medicine studies is based on the combination of basic sciences and clinical sciences and it is crucial to convince the students of the importance of both. Students are often not prepared for the so-called theoretical part and they are disappointed by studying anatomy, biochemistry or physiology instead of clinical subjects. Moreover, students are not prepared to "learn" in an academic way other than in secondary school. Lack of success in the first years of learning may be related to the improper way of gaining knowledge and new information. The first years of study are often overloaded with an excess of new information that seemingly requires only mechanical memory. In most cases, it should be understood and remembered in the form of a coherent and logical sequence of information. Students often underestimate the need for oral learning and free communication, which will be necessary in the future in contacts with the owners of their patients. The role of teachers is not only to convince students and motivate them to deepen their knowledge in these disciplines, but also to show how to effectively study a lot of data in a short time (1).

The disadvantage from the teacher's point of view is the fact of large administrative groups of students during practical classes, which leads to the anonymity of students and the omission of students who may need additional care and help.

Teachers should be professionally prepared for the didactic process to make it effective and also teacher-friendly. Especially as adult learning has its own regulations, different from those for primary or secondary schools. Teachers also come under pressure when students do not achieve expected learning outcomes. Training providing the necessary information and tools for appropriate teaching would be very helpful, especially since more and more students require individual and special care.

Students should have the opportunity to develop their interests and motivation. They should be able to develop all cognitive abilities, such as thinking, ability to observe, imagination, memory, attention, as well as

emotional aspects accompanying the learning process. Achieving intellectual satisfaction is a key process of effective learning and raising motivation (1).

The effectiveness of the didactic process depends not only on the teacher, but also on the individual characteristics of students and their motivation. Moreover, the processes of studying and memorisation are based on brain biology and memory training, which require deep commitment and systematic work.

The Syllabus is a very important tool for teachers. It clearly defines learning outcomes that should not be modified, as each graduate should obtain the same level of knowledge, competences and skills regardless of the year. However, teaching aims can be adjusted depending on the prior knowledge of the current student group. Each year the group of students is different and is heterogeneous. Depending on the level of heterogeneity, teaching aims should be adjusted to minimize these differences. Therefore, teachers should rather think not about what to teach, because this is in the syllabus, but how to teach so that students can effectively "breath in" necessary knowledge and "breath out" during formative assessment.

Nowadays, when teachers should focus on their own scientific career related to points, manuscripts and other parameters, it is not easy to find time for students and build authority, motivation and intellectual satisfaction of students.

The aim of this study was to acquaint the reader with available innovative didactic methods and own experience from the Department of Biochemistry, Faculty of Veterinary Medicine in Lublin.

Brain biology and the remembering process

Studying and remembering new knowledge are based on biochemical processes and anatomical structures that may participate in them. The brain, together with the entire nervous system, is a structure with great morphological and functional diversity. It constantly receives, analyzes, and stores information from the environment and signals from the body. Many areas of the brain are involved in memory processes, and their specificity depends on both the type of memory and the phase of this process. They are connected by a network of distributed neurons that enable the information to be processed, stored, and extracted. For example, a given piece of information may be encoded in one area of the brain and then processed in other brain structures, which means that memory processes are processed in a fairly integrated and closely interacting system (17).

Numerous experimental data confirm the importance and involvement of the medial part of the temporal lobes, prefrontal cortex, diencephalon, cerebellum, in particular the limbic system, and, above all, the hippocampus in memory processes (40).

In terms of the learning process, the most important structure is the limbic system with the hippocampus, which plays an important role in creating and organizing memories (19). It is also the place where information is stored in memory, which allows it to be processed and used in the future. In primates, this structure additionally has a mechanism for transforming short-term memory into long-term memory, combining verbal and symbolic thinking into information used for decision-making (20).

Long-term memory is divided into explicit (declarative) and implicit (non-declarative) memory. Explicit memory is the conscious and intentional recall of actual, previous experiences, knowledge, and concepts. Implicit memory is unintentional and unconscious, includes skills, and enables faster and better performance (41). The hippocampus is responsible for both implicit and explicit memory processing (15).

To characterize the mechanisms of knowledge acquisition, it is helpful to distinguish between mechanical memory and logical memory. Mechanical memory means remembering content that is incomprehensible to the learner, which makes it impossible to later use the knowledge and draw conclusions from it. Logical memory, in turn, involves remembering new content using associations and connections that allow the use of acquired knowledge in practice. Despite the possibility of remembering a large amount of material using mechanical memory, studies in humans have shown much greater practical use of content acquired using logical memory than using mechanical memory (2).

The hippocampus is an elongated, three-layered structure located deep in the temporal lobe, at the back of each cerebral hemisphere. The hippocampus contains two parts: the Ammon's horn and the dentate gyrus. To discuss memory processes, it is important that Ammon's Horn contains various types of neurons that have both autoreceptors and heteroreceptors, which can respond to their neurotransmitters as well as neurotransmitters secreted by neighbouring neurons. After binding to an amino acid neurotransmitter, autoreceptors take part in transmission, either through excitation (e.g., glutamic acid) or through inhibition (e.g., gamma-aminobutyric acid; GABA). This means that they mediate a positive or negative feedback loop and they are therefore responsible for autoregulating the release of their neurotransmitters (7).

The learning process often initiates a mechanism broadly referred to as neuroplasticity. This term describes the ability of brain neurons to adapt and change in response to new experiences. It includes changes at the morphological level, as well as biochemical and pharmacological adaptations (intracellular pathways, receptors, synaptic proteins), changes in neuronal networks (changes in connectivity, dendrite remodelling, and the number and morphology of dendritic spines), and the generation of new neurons (23). From a biochemical point of view, neurons play an important role in memory processing and storage of neurosteroids and neurotransmitters.

It has been confirmed that neurosteroids are synthesized in most areas of the brain (30). The substrate

for the synthesis of neurosteroids is cholesterol, which is converted into pregnenolone (PREG), and PREG is then transformed by various enzymes into other neurosteroids, including PREG sulfate (PREGS), dehydroepiandrosterone (DHEA), estradiol and others (46). Neurosteroids are involved in the development of neuronal plasticity, cognitive functions, mood control, and social and sexual behaviour (13). Moreover, they are also thought to play an important role in the process of memory formation (48). Numerous studies show that some neurosteroids enhance learning and memory processes in the hippocampus by stimulating or inhibiting synaptic transmissions (3, 48). The increase in synaptic activity in the learning process has been defined as long-term synaptic potentiation (LTP). This leads to an increase in the effectiveness of the excitatory effect of the synapse on the nerve cell and to the reconstruction of the synapse structure. Stimulation of the presynaptic fiber causes the release of the transmitter – glutamic acid. There are two types of ionotropic receptors for this transmitter in the postsynaptic membrane – NMDA and AMPA (38). PREGS and DHEAS modulate the release of glutamic acid from presynaptic terminals in hippocampal neurons (33) and act as stimulators of AMPA and NMDA receptors and inhibitors of GABA receptors (44). Estradiol also acts as a stimulator of NMDA receptors and an inhibitor of GABA receptors (21). On the other hand, allopregnenolone (AP) and 3α,21-dihydroxy-5α-pregnan-20-one (THDOC) act as stimulators of GABA receptors and hence are known as GABAergic neurosteroids (4). Therefore, increasing evidence indicates that some neurosteroids are important endogenous modulators of learning and memory consolidation processes in hippocampal formation. Numerous studies on learning and memory focus on the influence of neurosteroids on brain synapses (27, 35). The extent to which locally synthesized endogenous neurosteroids in the brain contribute to these actions in the hippocampus still requires further research and better understanding.

Specific neurotransmitters are also involved in memory processes. Neurotransmitters are chemical compounds that transmit signals between neurons through synapses, as well as from nerve cells to muscle or gland cells (7). It is suggested that individual neurotransmitters, such as adrenaline, dopamine, serotonin, glutamic acid, GABA and acetylcholine, are involved in memory formation processes (32). The communication between neurons that depends on them is crucial for the creation of new memories. The cyclic activity of neurons leads to an increase in the number of neurotransmitters in synapses, as well as an increase in the number of synaptic connections. This process leads to the consolidation of memories (7).

Knowledge of brain biology and the processes related to learning and memorization may help teachers to perform the didactic process in a more efficient way and use the potential of students.

Experience about innovations in didactic process

Biochemistry course

During the didactic process in the Department of Biochemistry, we use different methods to assess students' learning progress. We believe that a variety of assessment techniques, adapted to the students' current level of knowledge, allows us to better prepare future veterinarians for their profession. We use formative and summative approaches. In formative assessment, feedback is provided to students (by themselves, peers, and teachers) to enable them to improve as they engage in the learning process. This form may be both informative and instructional in nature and allows for any modifications in learning process during semester. In turn, summative assessment summarizes students' achievements and measures their qualifications through examinations. This form verifies whether they have achieved the learning effects set for them by the teacher and included in syllabus (5). Through a multifaceted approach, students learn how to apply their knowledge, to reason scientifically and clinically, as well as to think critically and analytically.

In our laboratory classes, students primarily gain skills in the practical application of biochemical knowledge. Therefore, in addition to the requirement to be prepared in basic theoretical topics, our team assesses students' thinking and their ability to connect facts logically. Individual issues assigned to specific practicals are posted on our website where students can freely access them. We use a flipped classroom, a blended learning technique combining additional learning materials reviewed before classes with active face-to-face classes. This method engages students and solves the problem of limited teaching time in the conventional teaching model (lecture, auditorium) by allocating time in the classroom for the practical use of the material that students learn before classes (51).

Laboratory classes begin with a short announced quiz in the form of multiple-choice questions covering the material discussed in the class. This form of assessment is a frequently used technique for verifying declarative knowledge in relation to a slightly demanding cognitive process and recognition (5). The aim is to engage students in self-preparation, to focus student attention on the topic, to learn the objectives of the classes, to ask them to acquire the basic knowledge related to the lesson and to perform the experiments efficiently. The results of the short test give us information on whether the students are adequately prepared for the class. A frequent observation is the correlation between the quality of execution of the practical part and the quiz score. A worse score in the entrance test is often associated with a greater problem in performing the experiment correctly in the scheduled time. Students therefore know how important it is to make an effort to work on their own before classes to acquire practical knowledge. Students gain points in each test, and in order to pass the

laboratory part of the course it is required to obtain at least 60% of the total points earned during the semester. This form of assessment, although mainly evaluating theoretical knowledge, is also intended to motivate students to be systematic. Working throughout the semester has a positive effect on the process of memorizing and consolidating the theory covered.

In the next part of the classes, students face laboratory tasks. Our observations show that practical activities are undoubtedly an excellent training in analytical thinking. According to Golding, we can identify whether a student is thinking about the task, by observing specific behaviors. Furthermore, what a student does during assigned tasks can serve as an indicator, providing us with criteria to assess whether the student is focused on the task (22). The quality of the experiments performed, as well as their understanding by the students, is assessed by us at the end of the practicals. We evaluate whether all tasks have been completed, whether the results are correct and whether the student is able to draw conclusions on his own. Although students work in groups of 2-3 people, we require that each team member fully knows the course of the experience, its results and is able to correctly interpret and explain the obtained results. The assessment is made after the students in a given group provide oral answers. The result of this is that students are awarded an appropriate number of points for performing the experiment and for responding to the obtained results and conclusions. Thanks to this, we can assess the student's practical skills and teamwork, as well as logical thinking, the ability to explain and formulate conclusions, and therefore combining theory with practice.

Additionally, students are obliged to write a report on the lab classes and submit it to the next class. The report contains questions formulated in such a way as to assess students' ability to explain, describe, prove and apply the acquired knowledge. Reports are also scored on an appropriate scale and, as in the case of entry quizzes, we require at least 60% of the total number of points obtained during the entire semester for the tasks, answers and reports. This form of activity forces students, already equipped with the results and conclusions from the experiments, to return to the tasks performed during the practicals, which allows them to fully understand and remember their purpose.

One of the additional works to be completed during the semester is to independently write an essay on a selected topic from the list prepared by the teacher. Here we assess the selection and correctness of the content, the structure of the paper (goal, development, summary), selection skills and the choice of references. Students are assigned points depending on the level of advancement of the prepared essay. The main goal of this assignment is to teach the student to think critically, analytically and scientifically.

Once a semester, instead of laboratory classes there is a seminar where we use the Jigsaw teaching technique to promote active learning. In this method, each student is an "expert" in a given field. Students in a particular group must work together to become experts in that field and pass on knowledge to students who are experts in another field. It is mainly about exchanging expert ideas. The leader asks students questions and any member can ask them. Research has shown that students learn more by teaching others. This often results in a greater understanding of the topic being discussed and, as a result, better grades (14, 16). Generally, the main goal of Jigsaw learning is to improve the learning of a student who takes on the role of a teacher during the game. The student's task is to teach a group of students a given part of the material prepared by the teacher. By taking on the responsibility of teaching others, the student strengthens his or her memorization skills and the entire learning process is then enhanced (27). Over the course of several years of using this method, we have observed that our students respond positively and become more active during such classes. On the other hand, however, the task is demanding and not as easy as one might expect. For now, we have not introduced a grading system for this part of the classes, but we will probably introduce an element of gamification to this strategy in the future.

The main component of the grade at the end of the semester is the average grade from the colloquium which takes place a few times in both semesters. This formative assessment helps to find out if teaching aims and learning effects are stated adequately and our teachers have time to correct teaching aims if necessary. The advantage of this form of assessment is that it evaluates both theoretical knowledge and logical thinking skills. A well-prepared student knows the main ideas, but also the details. The oral form of assessment, which takes the form of a conversation, opens the possibility of discussing problematic issues. Thanks to this, we can assess the ability to think analytically and deductively, which are highly desirable skills in the work of a veterinarian as well as ability to communicate which is important for further contacts with owners of patients. On the other hand, the question arises whether this form of knowledge check is objective. Unlike a multiple-choice test, there is no specific number of points that can be easily converted into an assigned grade. Additionally, the oral form may be considered more stressful by shy students. Therefore, despite the benefits of choosing an oral form of evaluation of knowledge, such as prompt feedback, for us academic teachers, making an equitable and objective assessment becomes quite a challenge.

The most important grade is the exam grade, as it ultimately determines whether the student will receive a passing grade and pass the course. The purpose of this summative assessment is to verify how well students learned what was intended to be learned. The material to be covered in the exam includes both lecture content and that discussed in laboratory classes as well as

knowledge from virtual cases (described elsewhere), and is therefore a summary of all the knowledge and skills acquired during the one-year biochemistry course. We know that the enormity of the issues to be mastered can be a considerable mental effort and stressor for students. Therefore, students who have studied systematically and conscientiously for two semesters achieving high marks in the laboratory classes have the opportunity to take the exam before the actual first term. The oral form is an undoubted advantage here. Other students take the exam during the session in written form, where they are confronted with various types of tasks aimed at assessing not only theory, but also the ability to compare, make selections, make assignments, think logically and critically, and apply their knowledge in practice. The most important benefits of summative assessments include transparent and effective measurement of learning outcomes and the creation of a holistic and comprehensive learning environment. Moreover, it motivates students to support self-development, prepares them for real-life challenges in their future profession, and also allows for maintaining constant quality and educational standards. On the other hand, the use of summative assessment by the teachers can be somewhat stressful for some students and may encourage them to focus on getting grades and neglect deeper learning. Indeed, the ideal is to keep the right balance between motivating students and instructing them to achieve their learning goals, so that assessments do not put pressure on students while promoting effective learning. Well experienced teachers, however, can do a better job than any test with questions of bad quality.

Generally accepted ways of assessment cover: (i) clearly defined percentage of positive answers for passing, (ii) evaluation of progress – passed/failed and (iii) degree of passing established after the estimation of prior knowledge – adjusted to current needs. All have advantages and disadvantages. Using the first way before checking prior knowledge may bring disappointment and a low success rate. Using the second may be less motivating to students. Using the last seems to be more safe as it gives the chance to modify the assessment depending on the current group of students. Learning effects have to be obtained but the way to achieve them can be different depending on different groups of students.

In summary, we propose a multi-criteria method for assessing veterinary students' knowledge and skills in order to make the most accurate and reliable assessment of their achievements during the biochemistry course. Similarly important is the feedback to both students and teachers.

Chemistry course

The chemistry course is a semester-long introduction to more complex biochemistry. This forces us to focus on truncated topics, which require further understanding of more complicated biochemistry concepts without time to repeat high school material. The course consists of lectures (15 h per semester) and practical classes (30 h per semester). The classes are mandatory for students and during them they perform laboratory exercises every week, which may stimulate their imagination and allow them to master appropriate practical skills, chemical procedures as well as chemical calculations necessary to be properly prepared for the biochemistry course. Our chemistry course also uses a flipped classroom method, with quick verification of knowledge using the Socrative platform, on-site experiments and the reports after practicals that summarize and draw conclusions about what was done and why. Formative assessment throughout the semester and clear feedback for both students and teachers are prepared. Summative assessment takes the form of a single-choice test. The quality of test questions is rated through statistical analysis by the use of adequate software (www.testy.com.pl/). As part of the assessment, a statistical analysis is performed: including the average score, test reliability, discriminating power of the tasks that allow assessing the ease of the task, discriminating power of tasks and the percentage of missing test tasks.

However, there are difficulties we have to face. Recruitment for veterinary medicine at our university does not include chemistry as a mandatory subject. As a result, an increasing number of students begin our chemistry course with a lack of basic knowledge. This causes that groups of students are heterogeneous with regard to their level of knowledge and it requires checking their prior knowledge and adapting teaching aims to the current situation in order to obtain the same learning outcomes every year. Moreover, studying at a veterinary school is associated with acquisition of very large parts of the material from many subjects in a relatively short time, which requires gaining knowledge in an effective way (logic, not mechanical memorization), often different than in secondary school. A solid foundation in chemistry is very helpful in the first weeks of studies. There is an optional subject available for any students who needed help understanding the basics. This situation confirms how important pedagogical competences and teaching tools are to meet these challenges and not discourage students from the beginning.

Competition for ideal didactic tools

Since 2015, the Department of Biochemistry has been announcing a competition for ideal didactic materials. The aim of this activity is to consolidate students and enable them to study the material based on willingness and motivation, rather than the need to pass. It helps to understand students' changing expectations, their creativity and the way they learn as these ways change over time. Participants can be students of the third semester of veterinary studies. In the first edition in 2015, 4 projects were submitted, but over time, many more projects were submitted, up to 66 projects in 2023. 164 students were engaged in these 66 projects. Projects are evaluated in 3 categories: behaviourism, instructivism, constructivism. Proposals in the behaviourism

group included: flashcards or applications for studying chemical structures of important molecules or pathways using a PC. The instructivism group included PDF files with the description of particular parts of material, Prezi files, animations, or applications for PC and iPhone, while in the constructivism group included, in majority, board games based on already known scenarios, but with biochemical questions, as well as additional crosswords. Students create short movies, poems, songs and many other forms of studying biochemistry. From the teacher point of view, the advantage of this activity is not only raising motivation through competition, but also studying selected topics during inventing the project. From the student perspective, this means working together with classmates and learning through fun and games. First places in all three categories are awarded to books. On the one hand, attempting to create ideal didactic material stimulates students' imagination and allows them to comprehensively develop a given topic without limitations. Students often deliberately choose a range of material that is difficult for them so that they can go through it again and approach it from a different perspective. Independent preparation of didactic material allows the student to better understand and remember it, as it can be presented in a less complex way and be equipped with numerous associations and comparisons known to a given person. Conversely, thanks to these projects, we teachers can better understand how students associate particular issues related to biochemistry and what helps them remember difficult parts of the material in a more accessible way. Getting to know a different point of view, especially from an inexperienced person who is still learning, allows for better adjustment of the teacher's way of transmitting knowledge. This meeting of two often different perspectives can help to improve the learning process, to the benefit of both student and teacher.

Selected projects are available in University Library.

Virtual cases

In 2012, our teaching team together with co-workers from Biochemistry and Physiology in Hannover and Budapest, the E-learning Department from Hannover, as well as computer company from Munich, applied for an EU project covering the studies on the usefulness of virtual cases in teaching basic sciences for veterinary students. This resulted in the creation of 30 virtual cases related to evidence based medicine and a selection of popular cases from veterinary practice. The cases are available upon request on the CASUS platform. More details can be found at www.vetvip.eu

The cases have been in constant use in our Department since 2014. When working with these cases, students may take on the role of a doctor and participate in diagnostics and therapy, making clinical decisions based on the information and didactic materials available in the program. Feedback on the decisions made and effectiveness of the selected steps is provided immediately. Medical malpractice (error) has no consequences at this point and can be clearly explained. The digital platform provides tools to produce the whole material in an attractive form of many different types of multimedia, text, photos, sound, video, and 3D animations. As the result of using virtual cases, it is possible to integrate theoretical and practical knowledge in the education of veterinary medicine students, enhance the attractiveness of knowledge in basic subjects and strengthen students' motivation to study basic subjects. Moreover, students are familiarized with professional veterinary vocabulary, become motivated to learn independently, better understand the basic biochemical and physiological processes responsible for functional disturbances, and acquire analytical and synthetic thinking, problem-solving and decision-making skills. From the teacher point of view, participation in the project brought not only an improvement in the quality of education, but also the integration of teachers from different disciplines, collaboration between didactic units and the enrichment of methodological resources and their pedagogical qualifications.

Students like this form of studying and they are able to see biochemistry from a different, more practical and integrated point of view. It develops their imagination. Using cases resulted in better grading during summative assessment in the biochemistry course.

Masters of Didactics (MoD)

As part of the continuous improvement process of academic teaching, four employees of the Department of Biochemistry participated in the "Mistrzowie dydaktyki" (Masters of Didactics) project under Action 4.3 International Cooperation, implemented by the Ministry of Science and Higher Education from December 1, 2017, to December 31, 2023 (https://www.gov.pl/web/nauka/mistrzowie-dydaktyki-w-ramach-dzialania-43-wspolpraca-ponadnarodowa). Two persons participated in sessions at the Ghent University of Ghent from April 1 to 5, 2019, while another two persons attended training organized at the University of Groningen from January 26 to February 1, 2020. The main goal of the project was to introduce new solutions in tutor training and education through collaboration with leading foreign universities. Training sessions for university staff in foreign centres were conducted, and the observed solutions were tested in the home units in Poland. The project encompassed a full cycle of education at universities based on the tutoring method. The term 'tutoring' originally referred to individual teaching, but it is now understood in practice as the individualization of education, including all aspects of effective teaching and learning. In addition to being expert in factual knowledge, the modern academic teacher must stimulate the development of knowledge in the group, offer help when necessary, provide feedback, built a safe and supportive learning environment, etc. He or she should encourage students to participate in the learning process successfully, know how to manage students' interactions and cooperation in classes, how to manage time, etc. (9).

As has already been confirmed, tutoring is effective in the educating students, including medical students (1).

The training was aimed at acquiring the skills to conduct tutoring in large groups of students. Using educational platforms and electronic learning management systems to introduce blended learning, the flipped classroom is a valuable tool to support and implement this approach. This allows for an effective combination of individual tutoring, small group classes and multi-person lectures (9). The introduction of tutoring into practice makes it possible to simultaneously standardize and individualize the achievement of learning outcomes for all students, not only the most talented ones (25). In practice, the training under the Masters of Didactics program at the University of Ghent included three components: 1) a 40-hour study visit in Ghent, aimed at practicing the use of modern tutoring methods and tools related to the first contact with new students, techniques for raising motivation, as well as assessment and feedback tools, 2) a 20-hour online booster including extra online modules, online supervision with regard to educational project, and pre- and post-tests, and 3) good practice days in Poland including a 32-hour conference with demand workshops and 4) practical application of obtained skills by working with students during extra didactic hours. The Groningen program was similar.

During the project implementation, the practical sessions in home institutions were designed for students who wanted to enhance their skills and broaden their knowledge, as well as those who wanted to fill gaps and better comprehend the material covered during regular courses. For implementing gained experience, one person conducted biochemistry sessions with 7 students who had problems with passing biochemistry exam for 50 hours, one person conducted biochemistry classes for 4 students for 100 hours and one person conducted supplementary chemistry classes for 5 first-semester students and one person conducted supplementary chemistry classes for 6 students for 100 hours.

From the organizer's perspective, the project resulted in the development of documents containing educational materials and recommendations for Polish universities (https://www.gov.pl/web/nauka/rekomendacje-wynikajace-z-realizacji-projektu-mistrzowie-dydaktyki). For the participating staff, the project provided an opportunity to observe and benefit from educational experiences of recognized European universities. The experience gained enabled the implementation of innovative teaching methods within regular chemistry and biochemistry classes.

The experience gained during the MoD project allowed employees to optimize the process of conducting classes, which contributed to increasing students' involvement in the topics covered. It also increased the general level of knowledge acquired by students, measured by the increase in the number of positive grades in final exams in subjects in which the learned teaching methods were used.

Available tools for innovative didactics

Classical frontal lectures as part of the University's routine activities are currently not well evaluated by students. Students expect more interactive ways of involvement. Available teaching tools provide with ideas for making lectures more attractive. Practicals in the veterinary medicine course are usually based on laboratory experiments or contacts with didactic animals or patients.

Checking the prior knowledge

In other than classical forms of teaching, such as lectures or laboratory exercises, a variety of methods and techniques are increasingly used (depending on subject specificity) to provide veterinary medical students with the necessary competencies. Checking the prior knowledge at the first contact with new students is crucial to find a good way to minimize the heterogeneity of the student group. Moreover, it is possible to verify if existing knowledge is of declarative or procedural character. There are several methods of assessment, including "Word chain" or "Knowing, want to know, what have I learned?" which are educational tools in the form of a game. Participants exchange words, starting with one selected word or topic, and add words that are related to each other (for example, those that start with the last letter of the previous word). Students share what they already know about the topic, which allows them to summarize their current state of knowledge and finally share their reflections on what they have learned during the process. The method can also be used in writing, as a chain of notes. It begins with one student answering an open-ended question and passing the note to the next student to add their answer (https://app.secure.griffith.edu.au/exlnt/entry/8669/view). This exercise may encourage shy students. Introducing short quizzes can also help assess the knowledge of the group. Tests can be conducted in traditional or online form, using, for example, the Socrative platform. The teacher can create a test containing questions related to the topic that will be discussed.

Raising motivation/active learning

New approaches, inspired by both technological advances and new insights into the learning process, rely on interaction to involve students. Also, they supplement the theory with practical aspects in clinical subjects, including biochemistry, which demonstrates the relevance of the content presented. For this purpose, blended learning is used, which combines traditional teaching with online resources/technology (e-learning platforms, mobile applications). Online materials can include short video, graphics, a variety of problems and exercises that are provided to students. Before they go to classes, they first familiarize themselves with the materials, and then in class they are engaged in discussions, problem solving or practical applications of the knowledge they have learned. This is known as a flipped classroom, which allows students to learn in a more

flexible way, adjusted to their individual preferences and pace of learning. Additionally, it facilitates student-teacher interaction during class when students come to class with some knowledge (18, 36). Teaching methods that promote memorization only develop the ability to memorize facts. Modern approaches emphasize that learning is an active process and put students in the role of active participants in the learning process (constructive theory of learning), instead of passively accepting the knowledge imparted (instructive theory of learning). The first is questioning, that stimulates curiosity, which is why problem-based learning is popular. Another important aspect is doing things together, such as in group projects that involve students in interaction and cooperation. Finally, an important part of the process is reflection, which allows students to close the series of activities, provide feedback and understand their own progress in learning (11). Active learning methods, such as problem-based learning involves problem solving or case analysis to identify the cause. It requires students to think critically and seek solutions. Instead of a traditional lecture, the teacher acts as a guide. They provide support, ask inquisitive questions and offer feedback to help students navigate the problem-solving process. They also ensure that discussions remain focused and productive. Team-based learning is another example of active learning. Students independently review material (chapters from books, articles, and summaries of course material) and take individual tests (multiple-choice questions) in class. After completing the test, students form teams and retake the same test as a group. The group discussion aspect encourages peer teaching and cooperative learning. Feedback is provided after the group test allowing students to understand the correct answers and clarify any misunderstandings. Students then become involved in activities that allow them to use the knowledge they gained (24). These methods minimize class time spent on imparting information and maximize class time spent on students' practice of complex problems, using mutual learning in an "instructor-led" format (28). A method that also involves mutual teaching is Jigsaw, which involves dividing a group into smaller teams that are responsible for understanding a different, specific part of the material. Within their group, participants try to understand the assigned section of material by discussing, asking questions, taking notes, and creating summaries to clarify unclear points. Once the group work is completed, participants are re-aligned into new groups, which consist of one participant from each of the original groups. In these new groups, each participant is an expert in his subject area and is responsible for imparting his knowledge to the rest of the group members. Each of these groups becomes an expert in their field and they present the information they have learned in their original groups, allowing for the exchange of knowledge. This promotes cooperation, communication, mutual learning and understanding of the material from different perspectives. Another way to work in a group is carousel brainstorming. The goal is to organize collective mental activity in search of out-of-the-box ideas. Students are assigned to a group (preferably with different knowledge) focus on a specific topic, question or problem to brainstorm. They are provided with materials such as whiteboards, sticky notes or flip charts on which participants can write down their ideas. Each group starts with a different brainstorming 'station', and at each station participants have a set amount of time (e.g., 5-10 minutes) to generate as many ideas, solutions or answers as possible related to the assigned topic. After the allotted time, groups move to the next station. Each group leaves their ideas written at the previous station for the next group to review and use. As the groups go through each station, they continue brainstorming to find new ideas or develop existing ones. This process repeats until each group has visited all the stations. Once the carousel is complete, the ideas generated are reviewed. This may include sharing key insights and discussing potential next steps or actions. Continuing the brainstorming theme, there is also a technique called the Walt Disney thinking strategy, which is based on three different perspectives, as the Dreamer, Realist and Critic. In the first role, there are no limits, the dreamer allows his imagination to wander freely, even the most fantastic and impractical ones. The realist, on the other hand, transforms the ideas generated by the dreamer into an action plan. This group focuses on analyzing possibilities and developing concrete steps that lead to putting ideas into practice, taking into account real-world constraints and challenges. In the role of critic, you take on the perspective of an outside observer. The task of this group is to evaluate and critically analyze ideas and plans to find potential weaknesses, challenges and risks (29). Another form of interactive learning is the mind map, which can be used both at the beginning of contact with students and throughout the semester. An alternative to the traditional mind maps is the lotus flower. This is a technique that facilitates the search for a solution to a problem. In addition, the lotus flower applied during brainstorming helps to better direct and strengthen the group discussion. A method for fostering original thinking is constructing a cause-and-effect Ishikawa diagram, commonly referred to as a "fishbone" diagram (47).

Our Department developed competitions for the best teaching materials (described elsewhere in this article). Students can submit their materials, including lesson plans, exercises, educational games, multimedia presentations, etc., which use a variety of active teaching methods. By taking part, they can not only gain new ideas and inspiration to improve their teaching practice, but also have the opportunity to present their own ideas and experiments with others. The best materials are rewarded, which influences students' motivation.

As mentioned above, an element of the blended learning model is e-learning. As part of this, materials based

on virtual clinical cases in the CASUS platform have been developed as an e-learning tool (8, 26). Clinical integrative puzzles (CIP) are exercises that allow students to combine acquired knowledge with clinical reasoning and problem solving. For this purpose, disease scenarios (e.g., clinical cases) are designed that are similar but have key differentiating features that provide students with opportunities to practice required skills. The CIP is similar to an extended-match question format, and answers are selected from a list of choices. After the answers are completed correctly, a summary of the patient's illness is presented in the form of a discussion, ensuring that a common understanding is achieved (6). IT tools that also help and make the learning process more interesting are PowToon, Nearpod, Padlet, EDpuzzle and Wiki. Learning through video animation with PowToon software can help students understand the material (45). Similarly, Nearpod software. With the application, students can view educational materials during a lecture on their own electronic devices, such as smartphones, tablets and laptops. Teachers can share the slides of their presentations and add quizzes, surveys, drawing features, collaboration and open-ended questions, allowing students to interact with the content (10, 39). With EDpuzzle, you can share video files for learning. The program allows you to make sure your students have watched the entire lesson and determine whether they have understood the content, thanks to the ability to add quizzes and feedback. EDpuzzle has proven to be a very effective tool for engaging students in the biochemistry lab and can be used as a method of pre-laboratory preparation (42). Videos can also help facilitate lessons that include elements of instruction (12). Several digital tools foster student engagement through collaboration, including Wiki and Google Docs. A wiki-type site based on open collaboration, by creating a page allows a group of people to use information. It allows people to generate, share and edit content together. Students can enjoy learning with others because of participation in the digital space (50). Padlet (padlet.com) is also used for collaborative learning. It is useful for creating virtual online walls for sharing relevant content, such as questions, documents, graphics, videos. The platform can be useful in classes to engage students in discussions and questions during lectures (31, 43). A break from traditional classes is the use of game-based learning platforms. One example is Kahoot!, which is used to test students' knowledge. It allows teachers to use classroom content to construct quizzes in which students participate as players in a quiz show. This platform is used as an active form of break during our biochemistry lectures, and was also a teaching tool used during classes conducted as part of the Masters of Didactics program.

Assessment

Other tools based on SRS (Student Response Systems) also include Socrative, as well as Quizlet (49) or Mentimeter. Also worth mentioning is a multiple-choice question generation system called PeerWise. It is the students who create, answer and evaluate questions from other students, and teachers are involved in reviewing the questions. In addition, the system allows you to rate questions by difficulty and quality and provide comments (discussion forum). It is possible to follow favourite authors and ask for help or clarification on specific questions (37).

The teacher can create a test containing questions related to the topic to be discussed as well as the specificity of the subject. The questions can have different types, such as single/multiple-choice, true/false, short answer or open-ended, and through their mobile devices or computers they can solve the test. After completing the test, the teacher can quickly review the results and see what answers the students gave. The results can be used to adjust the lesson plan, taking into account areas where students are struggling or need extra help, or as a benchmark in the process of evaluating students' progress so-called formative assessment or summative assessment at the end of course. The quality of these questions is extremely important. Wrongly prepared questions will not play their role and will not evaluate knowledge, skills, ability to think etc. Statistical analysis of questions and answers done by adequate programmes may help to evaluate the quality of test questions and the same quality of obtained results of assessment (discussed elsewhere in this article).

Effective learning methods focus on combining new facts with existing knowledge and making connections between different pieces of material. With regard to learning clinical subjects, it is extremely important not only to connect information within the discipline itself, but also to link it to other disciplines. For future veterinarians, it is particularly crucial to understand the connections between biochemistry, general anatomy, histology, embryology, physiology. The use of various forms of education can contribute to more effective learning and better preparation for the challenges facing veterinary medicine graduates. Clinical subjects have own specific tools for the evaluation of clinical skills and clinical reasoning such as OSCE or MiniCEX.

Didactic training of teachers allows them to make didactic process interesting for students and effective for teachers. It can be obtained by freedom in the selection of available methods and forms of education by well-prepared teachers. Available tools should be selected by teachers depending on the specificity and requirements of the subject. The overflow of detailed information puts students under pressure and, as a result, they rely on pure memorization of facts. This approach can foster a negative view not only of the relevance of biochemistry, but also of other subjects. Therefore, in the study of biochemistry, a combination of various didactic techniques proves to be effective, activating students and strengthening their logical thinking skills. The courses conducted in our Department are diversified so as to form in the student the various qualities

needed for his/her future profession as a veterinarian, and moreover can bring more satisfaction to both students and teachers. It can be easier when teachers are well prepared from pedagogic point of view.

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