Academic achievements of medical student related to interactive problem-based learning in blended learning context

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Article Info

ABSTRACT

The purpose of the current study is to prove the effectiveness of using interactive elements in problem-based learning (PBL) for medical students. The simultaneous use of interactivity and a problem-solving approach makes it possible to improve the pedagogy of distance learning and improve the training of medical specialties. In the study, 120 medical students of 4-5 university courses were enrolled and were divided into 3 groups, a control group and two experimental ones, who received intervention one in the form of PBL, the second, PBL, and also interactive elements in blended learning. Participants in the groups were randomly selected but with an equal representation of men and women aged 21 to 23 years. The results were measured using the university 12-point system and the presence of statistically significant differences was established using the student's t-test. It was found that in experimental groups, the results of the post-test of academic achievement were statistically significantly higher than the pre-test. At the same time, the best changes were recorded in the group with PLB and interactive training. There were no statistically significant differences between genders within each group or between groups; however, females performed slightly better on average than males. Practically, the results of the study can be used to improve the academic training of physicians during distance learning and to improve practical problem-solving skills. The current study can be used in further analysis of the PBL of medical students subject to the global integration of digital technologies in educational systems.

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1. INTRODUCTION

Problem-based learning (PBL) is an effective method based on finding necessary information outside the classroom, creating projects, and solving problems with students [1]. It is an active learning method that helps develop higher-order thinking skills, communication skills, and creative and critical abilities, as well as improve student performance [2], [3]. PBL was presented to improve the process of learning medicine by researchers [4], [5]. The use of this learning method should encourage students to think and solve problems independently in real-life situations, evaluate and solve clinical problems, and develop

reasoning skills. Several research [6], [7] emphasizes the need to develop and implement student-centered teaching methods, as well as problem-oriented methods.

According to the study of Aslan and Duruhan [8], a virtual learning environment developed based on the PBL approach was effective for students' academic performance and problem-solving skills (the experiment was conducted with 68 students of the 7th grade in a general education school). Using the method of PBL in the context of classroom education improves students' creative thinking, stemming from the ability to generate new and rational ideas that can solve current problems effectively [9]–[11]. Other authors have pointed out that mobile learning using the iPad is compatible with the pedagogy of PBL and can create a new pedagogical model of mobile learning [12]. However, Lin and Wang [13] argue that the use of computer technology in PBL is only effective when it is used as part of active and engaging learning.

The use of PBL is relevant since the specialists are required not only to know the necessary information about the characteristics of work but also to know how to use it to achieve the goals of companies or institutions. Teaching how to apply theoretical knowledge in practice prior to employment is a current trend in educational institutions [7]. Learning through problem-solving also promotes digital skills, communication skills, creativity, and critical thinking [14].

Employers face problems with the low level of practical training of young professionals precisely because of the inability to adapt to social conditions, lack of experience, outdated certain techniques, and lack of necessary digital skills. To organize practical training, a dual education system is used: an integration of education in an educational organization and directly in the workplace. In this way, students will be optimally prepared for the work environment [15].

The use of PBL led to significantly better theoretical test scores and higher levels of student and teacher satisfaction with the process and outcome of learning. It is an effective way to develop students' comprehensive abilities to perform real clinical laboratory work, and the researchers Li *et al.* [16] described it as a promising teaching method that should be extended to all curricula subtypes. Zhou [1] developed recommendations for implementing PBL in Chinese universities and stressed the importance of developing creative skills using this method. However, there is still a need to improve this method, considering the student's specialization and field of study.

In general, it should be noted that PBL is a significant enhancer of learning, especially when it comes to working with people (in this case, medicine). At the same time, the problem put forward most often requires students not only to solve it directly, but also to develop a set of related skills (argumentation, leadership, discussion skills, and stress resistance). Nor should one overlook the importance of an educator in the context of providing an effective learning process: a student's level of independence is determined by the initial aspects of a teacher's demonstration of processes.

The aspect of PBL is the exclusive prerogative of many scholarly publications of our time. However, a rather small number of manuscripts explore this issue in the context of medical education through the use of a blended learning approach. The hypothesis of the current study points to the possibility of using online and offline teaching methods with problem-based case studies that are able to maximally adapt students to the realities of clinical work. Given the development of technology, widespread distance learning, and the positive results of the PBL method in traditional and other forms of education, it is necessary to plan the application of this method in various forms of medical students' education.

Informal forms of learning and self-learning are already a necessity and an everyday norm for people in the 21st century [17]. Today's digital society requires that the learning process meets societal requirements [18]. Widespread quarantine measures increase the importance of implementing effective distance learning methods, as the lack of communication during quarantine does not change the knowledge and skill requirements of future professionals [19]. At the same time, the ease of use of e-learning systems can have a positive impact on learning outcomes [20]. Universities need to develop the right combinations of functions and processes for the effective impact of digital applications on learning outcomes and processes [21].

As stated by Ssemugenyi [22], PBL can be applied to hybrid, blended, or online learning concepts. Some of the problems in PBL can be solved using technology [3]. For example, a web-based system for PBL developed by researchers had a positive impact on learning outcomes and included: i) material retrieval, ii) a discussion and brainstorming area, iii) a project planning and discussion tool, iv) an area for private groups to discuss learning objectives, v) an area for demonstration of work, and vi) tools for presenting developments and learning resources [3].

Research shows the success of adaptive innovations in online PBL classes [23]. Researchers implemented sessions consisting of eight students and one moderator, with students taking turns in eight roles in each session: leader, innovator, explorer, writer, reader, synthesizer, inquisitor, and audiovisual specialist. Participants can switch roles and find effective problem-solving techniques in each role, which increases behavioral flexibility and soft skills.

Many researchers are developing original methods and approaches to PBL. The hybrid PBL system developed by Yip has many advantages for student assessment over traditional instruction [11]. However, the author strongly recommends using this method with undergraduate students because they have the necessary background knowledge, are more motivated to self-study, and are more likely to learn effectively.

Mistry *et al.* [24] argued that digital PBL is a popular, effective, and efficient learning method, which should be carried out together with practical teaching methods. A study conducted at the virology department of Strasbourg University Hospital, France, showed a higher percentage of satisfaction with the PBL program (100%) compared to lectures and presentations (53%) [16]. Teachers in medical education are increasingly focusing on using this method to teach effectively and appropriately [14].

The use of digital technology provides an opportunity to increase the level of motivation, identify creativity, and develop interest in activities and information competencies. The use of digital technology enables training and professional development regardless of the location of a student or employee [25]. There is still a huge number of questions about learning with the methods of problem-oriented learning and distance learning [26]. For example, a survey of a large number of students regarding the introduction of massive open online courses (MOOCs) in the Russian Federation, in which 2000 students participated, showed that all 100% considered it best to study in an equally mixed and distance format [27]. In turn, researchers pointed out that the use of visualization and informal learning environments improves student outcomes, critical thinking, and problem-solving skills [28], [29].

According to Trullàs *et al.* [30], students at the University of Missouri, Columbia School of Medicine, where a ten-year analysis of PBL effectiveness was conducted, had fewer hours of instruction and, at the same time, better learning outcomes than students in a traditional program. Researchers indicate that to improve and disseminate distance learning technologies, it is necessary to develop and implement innovative technologies, revise curricula, and design learning processes [31]. According to the experiment results, the inclusion of an online component can complement personal PBL through increased access opportunities for students and teachers. This is about the benefits of remote access and organization of classes, as well as the inclusion of audio-visual components (interactive whiteboard, presentations), which improve the perception of information and learning outcomes [23]. Lazarenko *et al.* [32] pointed out the importance of using practice-oriented and various other innovative methods in the era of adapting higher education to the conditions of digitalization. A round table on 'medical education in the era of digitalization' was held as part of the XI All-Russian Conference with international participation in Medical Education Week 2020'. The round table related to learning possibilities in the digital transformation era.

Malmia *et al.* [33] examined the formation of an integrative form of student learning while maximizing the use of science and technology tools. It was found that a significant lever for improving PBL was the implementation of a conceptual teaching strategy for cartooning that promoted creativity and innovation as well as students' interest in understanding concepts. Researchers at a Malaysian university argued that the use of cartoons in teaching will improve the speed of generating new solutions [34].

Based on the low intensity of research on practical cases in online learning, the question of the optimal use of PBL in different educational formats arises. In this regard, the purpose of this study is to determine the possibility of applying PBL and interactivity elements for medical students. Research questions: i) does the application of PBL affect the improvement of the academic achievements of the senior courses of the medical university students; and ii) whether the interactive elements of the teaching strategy using a problem-based approach can significantly improve the academic achievements of medical students.

2. METHOD

2.1. Participants

The study included 120 4th and 5th year university students aged 21 to 23 with an equal representation of men and women (60 each). Participants were randomly selected subject to a specified age, university course, and equal gender representation. From the students belonging to the department of clinical specialties, participants of only the specified age were randomly selected. When one-half of the participants by gender was filled (reached 60 members, men), recruitment of men was stopped until 60 women were also randomly selected. Considering the total number of 4th and 5th-year students at the university, the permissible sampling error does not exceed $p=3.41$, which indicates that the sample is statistically representative of this general sample.

Students and instructors belonged to the Department of Clinical Specialties, which justifies the maximum level of interest in optimizing the educational process. Instructors were selected by referral from the university administration, and students by a separate specialty (4 groups of 30 people each). The groups were formed from study participants temporarily.

2.2. Study design

The participants were divided into 3 groups, each of which had different learning methods. Experimental group 1 received interactive learning with a problem-based approach. Experimental group 2 received only problem-based training without interactive learning elements. The control group received conventional instruction according to existing classroom teaching methods. Participants in each group were randomly selected to ensure equal gender representation (20 men and 20 women).

Before the start of the study and immediately after, a test of academic success was conducted on the basis of a 12-point system adopted at the university. The testing process was carried out by the same teachers of the studied discipline, who should take the exam in this discipline and in accordance with the requirements adopted in this educational institution. This test is not a specialized questionnaire or a specially developed scale but is an exact repetition of the university examination test in this discipline. The only change compared to the examination test was that the content of the questions was adapted by the teachers to the current level of knowledge of students who had not yet completed this training course. The reliability of the questionnaire was assessed using Cronbach's alpha coefficient. The scale for interpreting Cronbach's alpha values is as follows: >0.85 (excellent); >0.8 (good); 0.7 (acceptable); 0.6 (doubtful); and >0.5 (poor). The Cronbach's alpha value for the questionnaire related to attitudes toward learning was 0.81. Therefore, the questionnaire was reliable and suitable for conducting the research. Thus, an unbiased attitude to the results of the preparation of different groups and a uniform approach to assessment was achieved.

2.3. Intervention

For experimental group 2, a problem-based approach was used, which was expressed in the use of real clinical situations and problems of real patients as a starting point for studying each topic of the course. For the intervention, standard courses were used, which are studied in the 4th and 5th year of study; only the tools and technical methods of providing information and teaching methods have changed. Students were asked to find the answers to questions that arise when faced with the problem of a real patient and find the necessary sources. Collaboration and independent search were encouraged at the same time; each of the participants could choose an individual trajectory for finding a solution to the problem. In the course of solving problem-oriented problems, participants discussed the results obtained, found their own solutions, and then, with the help of an instructor, mastered academic knowledge and established protocols for solving the proposed problems. Observation of participants suggested that this approach increases motivation, and engagement in learning, and improves collaboration.

For experimental group 1, in addition to the approach described above, an interactive approach was also used. Its essence, within the framework of this study, was to provide feedback to students as quickly as possible using mobile learning, cloud services, and social networks. During the search for a solution to the problem, students had the opportunity to use pre-prepared data storage and exchange services, and interaction with instructors and teachers, as well as recommended sources on cloud services. Thus, students received a quick and proactive response to their comments, questions, and completed work or suggestions.

The control group received the same educational material in the form of regular lectures in the classroom, seminars, and practical classes according to the established academic course. The use of mobile devices and other services was left to the discretion of students and teachers and was predominantly sporadic and irregular. The learning of this group took place virtually unchanged compared to previous experience.

2.4. Data analysis

Statistica (version 18.0, StatSoft Inc., USA) was used for statistical calculations. Test results were checked using student's t-test in order to identify statistically significant differences between the results achieved by different groups. To conduct a parametric student's t-test, a study of the normal distribution of the sample was carried out using the Shapiro-Wilk method. The compliance of the sample with the criteria of normal distribution was checked both for the entire sample and for each of the three groups separately according to the results of the pre-test. The results of post and pre-tests of all groups were compared to identify the presence of significance of the changes achieved in each of the groups. The post-test results of all groups were also compared to explore possible differences in their results.

2.5. Ethical issues

All participants in the study gave written consent to participate in the experiment. No personal data was collected, stored, or used outside the purposes of the study. The confidentiality of participants' participation was guaranteed. Also, the intervention could not negatively affect the academic achievements of students, and this circumstance was taken into account.

2.6. Research limitations

The study measures only an objective assessment of students' academic achievements, but does not cover the measurement of their motivation, involvement, and other significant parameters that affect academic achievements. The sample represents only senior students whose cognitive skills have already been developed during their studies. Respectively, the results may differ for 1st to 3rd-year students with a different type of academic workload.

3.   RESULTS

A comparison of the average scores obtained by each of the groups before the intervention shows the absence of any significant differences between them as presented in Table 1. There were no statistically significant differences in any of the cases of pairwise comparison of groups, which is explained by approximately the same composition and level of training in each group. According to the results of pairwise comparison of the results of groups during the post-test, on the contrary, statistically significant differences are found between each of the groups (Table 1). It should be noted that there are differences between the experimental groups and the control group, as well as between the experimental groups. The experimental 1 group has the highest mean score (9.39), while the experimental 2 group has a significantly higher score than the control (7.86 versus 7.09, respectively), but significantly lower than that of the experimental 1 group. This may indicate that the use of elements of interactive learning at the same time as a problem-based approach is much more effective than using only a problem-based approach.

Table 1. Student's t-test results for pairwise comparison of academic achievement between groups during pre and post-test

		Mean	SD	df	t	p	Cohen's d
Pre-test	Exp. 1	6.21	1.02	119	6.491*	.921	.21
	Exp. 2	6.16	.93	119	7.219**	1.076	.011
	Contr.	6.39	.98	119	5.369***	2.163	.12
Post-test	Exp. 1	9.39	.66	119	1.98	.001	.794
	Exp. 2	7.86	.31	119	1.981	.019	.863
	Contr.	7.09	.64	119	1.98	.000	.802

*Exp. 1/Exp. 2; ** Exp. 1/Contr.; Exp. 2/Contr.

It can be assumed that in a situation of blended learning when elements and technologies of the digital environment are embedded in learning, interactivity is a natural and expected element of the learning environment, which is naturally embedded in pedagogical activity. An effect size study was also conducted for observed statistically significant differences to ensure that the magnitude of these differences actually had an effect. Cohen's d was used to examine the effect size (Tables 1 and 2, rightmost column). In the case of a pairwise comparison of the academic success of groups during the pre-test, the effect size is very small (.011 to .21 maximum), which corresponds to the absence of statistically significant differences. The success rates of the groups before the study were virtually identical. In comparison, during the post-test, the effect size for each of the pairs of groups should be found to be large (from .794 to .863).

Comparison of the mean and post-tests of each group separately as seen in Table 2 shows that for all groups there is a statistically significant difference in the scores. Thus, each of the groups progressed, but at a different rate of improvement. The highest rate was demonstrated by the experimental 1 group, below - experimental 2 group, and the lowest rate of improvement was shown by the control group, in relation to which no intervention was carried out. The effect size for comparing the pre and post-test scores of each group remained very small (d=.023) for the control group only. In experimental 1 group d=.921 and in experimental 2 group d=.832. The strength of the effect across treatment groups is very significant, indicating that the statistical differences estimated span the entire sample and are uniformly significant across the group.

Table 2. Student's t-test results to compare pre and post-test results for each group

		Mean	SD	df	t	p	Cohen's d
Exp. 1	Pre-test	6.21	1.02	119	1.981	.001	.921
	Post-test	9.39	.66	119			
Exp. 2	Pre-test	6.16	.93	119	1.98	.004	.832
	Post-test	7.86	.31	119			
Contr.	Pre-test	6.39	.98	119	2.910	.086	.023
	Post-test	7.09	.64	119			

*Exp. 1/Exp. 2; ** Exp. 1/Contr.; Exp. 2/Contr.

Studies similar to those described, based on student's t-test, were conducted to compare the results by gender in each of the groups separately. However, in no case were there statistically significant differences between the male and female half of the group in the academic results obtained. The strength of the effect in no case exceeded the value $d=.064$. At the same time, the female half of the groups recorded an average of 1.02 points higher results, which is not statistically significant and does not have sufficient power of effect. It can be assumed that the effect of the superiority of the female part of the participants may manifest itself to a significant level with an increase in the sample, which requires confirmation. Detailed gene comparison data are not offered here to save space and because they did not produce statistically significant results.

4. DISCUSSION

The data obtained confirm the assertions of several studies [2], [3], [6], [7], and that PBL methods are effective for learning in modern conditions and a distance form but have many aspects. It is necessary to carefully consider and plan the sequence of subjects, and the application of PBL methods during the study, and university teachers themselves must have a good command of these teaching methods. Interactive methods of teacher-student interaction combine the advantages of remote forms of learning and the possibility of using information technologies in the classroom (for example, software programs for teacher-controlled and independent learning) [35]. The study shows that interactivity significantly improves academic success for medical students. Lu and Tian [36] show the strong impact of interactivity in online learning environments on student academic achievement. Teachers must have a range of digital skills and be aware of the latest trends in medicine and the possibilities of using digital devices for treatment. According to the results of the round table held at Sechenov First Moscow State Medical University, this is one of the problems that must also be solved-improving teachers' qualifications [37]. Students' independent search for solutions to problems proposed in the teaching context requires regular mentoring from a qualified teacher, which was observed during the proposed study and is confirmed by other studies [26], [31].

The following stages of learning topics using problem-based methods should be in a distance format: studying the topic basics, independently finding the features and all aspects of the topic studied, and practical assignments to apply knowledge and skills (this one also takes place in different formats [38]. Classes should be held with active discussion, a teacher acts as a mentor or even an experienced doctor who supports or refutes the ideas that have arisen, together looking for solutions to problems, and asking leading questions. Such a step-by-step approach should facilitate effective learning [39].

Even though many studies demonstrate significant gender differences in the use of the studied teaching methods, in our case no such differences were identified [1], [6]. Women showed consistently better results without statistical significance, which may appear in a larger sample of participants. The lack of gender differences may also be partly explained by the presence of higher motivation and engagement in learning, which is characteristic of both men and women in PBL [8], [20].

When asked about lectures in a remote format, teachers unequivocally responded that they should not be held too long, because students are distracted. It is necessary to introduce various interactive elements in the format of presentations, and video lessons, but at the same time not to overload the information slides or class as a whole, because perception of information is reduced. It should be noted that PBL is not just independent learning, but the use of a number of methods by a teacher to encourage students to learn the material.

4.1. Challenges

Based on the analysis of academic sources, the following series of main challenges associated with blended learning and the use of PBL can be identified: students sometimes fail to complete assignments, students do the assignments without getting much into the material, given the lack of consequences (assignments are not graded, it is not an exam), students look for ready-made answers, do not consider many aspects (age, genetics, and comorbidities) [14], they can find unverified information (unreliable or generalized), they are too sure they know everything thanks to the information on the internet, but in practice there are more aspects to consider in treatment, online class time, preparedness of individual students, and their activity in class, students do not know how to take full advantage of digital technologies for learning [1], [7], [39]. Another difficulty of distance learning classes is the learning environment (home learning). It has been repeatedly proven that the environment affects the success of learning. Studying at home, although behind a computer with interactive platforms, does not allow students to learn to the same extent as attending face-to-face or practical classes. There is also no way to know if a student has completed an assignment on their own or with someone else's help; for example, checking all completed student assignments for plagiarism takes a lot of time. This confirms the assertions of Vaughan [40].

4.2. Advantages

The need to master the skills of working with digital devices. Elementary skills-connecting to Zoom, creating presentations, and searching for reliable information. More complicated the ability to work with the tools of virtual reality in medicine, which at the moment, even the university teachers themselves do not know. To implement problem-oriented learning in a distance and blended form, it is necessary to develop students' self-organization and self-learning skills. Teachers considered learning with a problem-based method in a distance form to be effective but rather theoretical and in need of practical expressions, discussion, and connection with practice. There is a problem with students' distraction, with weak memory of information due to the peculiarities of information assimilation from a computer [12], [16]. During mixed-format classes (when students prepared independently and discussed the material in a face-to-face format) the instructors noted improved student engagement due to personal presence in the class, lively communication, and the exchange of thoughts in the classroom with both an instructor and other students [2]. This shows the importance of live communication for learning and the factor of the necessary environment for learning.

Another problem of distance learning is the risk of issuing diplomas to people unprepared for work. All teachers unambiguously expressed that practical training is necessary, especially in the field of medicine. Virtual learning using any modern technology (virtual reality, participation in virtual operations, and performing them) is not comparable with practical experience, because when working with a computer one can pause, stop, or cancel the action, but in real life it is impossible. The personality of a patient (character, wishes, and emotions) also has an impact on the work of a physician. In a distance learning environment, there is a gap exactly in the practical experience. To solve this problem, mandatory practical training is needed for distance learning students. The use of PBL allows students to prepare for the conditions of real work better than traditional teaching. This is confirmed by the data of previous studies [7], [30] and meets the needs of the digital society [18].

At the same time, the best solution is to study in mixed formats or to use online lessons and online training as auxiliary elements rather than the main means of learning. The same results have been obtained by Akhmetshin *et al.* [27]. This is due to the factors of personal presence, live communication, the influence of the learning environment the issue of self-organization of students, and their ability and desire to effectively self-learn. However, again, these skills are taught in PBL.

Forms of examination or project defense can be online mode with certain conditions or face-to-face [21], [31], [32]. Efficiency in this case consists of two components: the student's own search and decisions and interaction with the teacher [31]. These are a consultation, a problem (conditions, diseases, complaints of a patient, and test results), solution options (not ready-made), and performing the operation online with various difficulties [21], [31], [32]. For exactly successful distance learning, with the help of apps, one needs a strong motivation to learn and to change. The skill of solving problems close to real life in the professional sphere creates a better-trained specialist. Without this, it is impossible to learn to pass tests online and get a diploma/certificate. This study offers an integrated approach to addressing these challenges to ensure hands-on training, academic success, and distance learning opportunities.

The methodology of practical heuristic testing of the possibility of effectively merging several methods to achieve a number of pedagogical goals shows good results in this example. The contribution of the research to practice is to demonstrate how PBL and interactive learning elements can be implemented in a simple and resource-free manner to improve academic performance in a complex medical specialty. The theoretical contribution of the study is to explore the parallel use of two indirectly related teaching methods and their heuristic integration.

5.   CONCLUSION

A blended learning format (a combination of face-to-face and remote classes) is the most effective. However, the opportunity to take an exam or perform an operation in virtual mode should also be limited to prevent unqualified people from getting a diploma and working in the medical field. The use of PBL is effective, interesting, and necessary, and this article presented possible options and patterns for applying this method in distance and blended learning. Developed learning forms with the use of problem-based methods, in general, were highly evaluated by both university teachers and students. The study involved 120 medical students 4-5 years of university, distributed in three groups, which used blended learning. One of the groups received no other interventions and was the control; two were experimental. One received a PBL intervention, the other received PBL along with interactive elements in blended learning. Academic achievement was tested by the university's 12-point system during examinations and the presence of statistically significant differences was checked by a parametric test using student's t-test. All groups demonstrated that the results of the post-test of academic achievement were statistically significantly higher than the pre-test.

The most significant positive changes in academic achievement were recorded in the group with PBL and interactive learning at the same time. This form of learning can be supplemented by a traditional or hands-on class to reinforce the results of the online study. Application of PBL methods requires rational planning of classes (it is illogical and ineffective to teach all subjects at the same time using methods of PBL). Gradual application will have a positive effect. Further research on this topic should be aimed at deepening the integration of interactive teaching methods into PBL and clarifying the role of the teacher in this learning system. The results obtained can be practically implemented at medical universities to increase the success and readiness of medical students for practical work. Also, PBL and interactive learning in the proposed form can help in the case of transition to a long-term form of online learning. The study covers only senior medical students and similar results for junior students who have not yet received significant training and cognitive learning experiences may differ in significant ways. Also, the use of PBL in other professional fields other than medical education has, as the literature shows, significant differences.

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