Improving teaching in different disciplines of natural science and mathematics with innovative technologies

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Abstract

The study describes an innovative methodology for teaching natural and mathematical sciences in the context of distance learning using modern technological solutions and based on the concepts of active social learning that involves constructivist, problem-oriented, project and research approaches. The proposed methodology was tested on 80 students enrolled in two training courses in [BLINDED] University and [BLINDED] University, respectively: *Mathematics Teaching* in the Content and Language Integrated Learning (CLIL) context and *Molecular Biology*. The psychological safety of the proposed pedagogical methodology was investigated by assessing the level of psychological well-being of the participants in the educational process using the Scale of psychological well-being questionnaire developed by C. D. Ryff that was adapted to the educational context. The results of the study showed that the proposed pedagogical methodology was safe in relation to the life of students. It generally improved their perception of learning and themselves in the role of its participants, promoted positive self-esteem in group learning contacts, and, by developing learning involvement and interest through the Clil technology, qualitatively contributed to the achievement of educational progress by each student. The developed innovative methodology for teaching natural and mathematical sciences can be used as a pedagogical model for developing effective training courses. The demonstrated assessment of the level of psychological well-being adapted to the educational context can serve as a basis for the development of motivational learning strategies that support students in crisis learning conditions during the pandemic.

Keywords Clil technology · Distance learning · Innovative teaching methods · Motivational learning strategy · Natural and mathematical sciences · Psychological well-being

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1 Introduction

The rapid development of information technology has led to the reassessment of the importance of many types of activities and a significant change in their nature (Melnikov et al., 2020). In the twenty-first century, the use of technology as a learning tool is becoming a crucial component of learning. In education, technology has introduced a new tool that can reinforce the skills of learners across all fields of study and age groups. Increasingly, the power of technology enables learning and interaction even in the most remote areas of the developing world. This digital revolution is fueled by the penetration of broadband and the ubiquity of smartphones, especially among teachers and students of the new era who are easily absorbing the trendy culture of leisure and learning. The introduction of innovative cloud technologies into educational processes gives students endless opportunities to participate in cutting-edge research and educational initiatives. Open educational resources in various formats such as videos, pdf and MP3 files are becoming the backbone of modern learning strategies (Iji & Abah, 2018).

There are great changes in teaching natural and mathematical sciences driven by technology and digital learning (Klingenberg et al., 2020). Due to the fact that natural and mathematical sciences should be integrated into the learning process as they are aimed at forming holistic ideas about the physical world, as well as the connections between objects based on leading ideas and concepts (Luneeva & Zakirova, 2017), most universities around the world include mathematics in many programs they teach. This reflects the vital role that mathematics must play in creating an innovative and productive workforce. Today, there are many open-source e-learning tools that make it possible to integrate technology into mathematics teaching (Akugizibwe & Ahn, 2020; Czerkawski & Berti, 2021). These models can help create learner-centered experiences that are interactive and supportive of the acquisition of scientific knowledge. The use of digital tools promote skills and strategies that are essential in the natural sciences, such as solving real-life problems or visualizing complex patterns. Adaptive digital tools allow students to receive content in accordance with their individual learning styles and implement the knowledge they gained earlier (Hillmayr et al., 2020). A specialist should possess a range of competencies. These include the ability for self-education, technology proficiency, independent decision-making, adaptability in the changing social and professional environment, teamwork, and stress tolerance. CLIL approach seeks to instill the exact same competencies (O'Dowd, 2018).

The COVID-19 pandemic has triggered considerable changes in higher education associated with the rapid transition to online learning and the re-configuration of physical and virtual learning environments (Bakker et al., 2021). The widespread adoption of stream-based learning is at the heart of the educational paradigm shift. Thus, teachers use remote communication tools to communicate and interact with students, as well as to deliver lectures and conduct classes through software interfaces in real-time. Meanwhile, students rely on online collaboration platforms and active group learning with peers. Given the importance of stream-based learning in the ongoing period of the COVID-19 pandemic, as well as its expected relevance

in the coming hybrid educational era, it is important to explore opportunities to improve the educational experience and seek innovative solutions to sustainably support quality digital pedagogy (Chen et al., 2021). In the context of distance learning, theoretical material is effectively delivered to students through audio or video broadcasting, text materials, or presentations. There is a serious problem related to the conduct of hands-on and laboratory classes in the field of non-humanitarian disciplines, where the formation of competencies occurs in the process of using laboratory equipment and interacting with technical means (Soroko, 2021). In addition, the COVID-19 pandemic has increased the need for interactive and engaging learning environments as the forced transition to distance learning has resulted in learning generally limited to discussions and lectures delivered through video conferencing tools such as Zoom (Childs et al., 2021).

In this regard, the purpose of the study is to develop an innovative methodology for teaching natural and mathematical sciences in the context of distance learning using modern technological solutions that support educational practices. The following research tasks have been set:

- to develop an innovative teaching methodology based on the concepts of active social learning using the modern approaches of STEM education, Content and Language Integrated Learning (CLIL), namely constructivist, problem-oriented, project and research approaches, and implement it into an online training course;
- to test the proposed teaching approach on students taking the Mathematics Teaching courses and Molecular Biology in the [BLINDED] University and [BLINDED] University;
- to assess the level of psychological well-being of the participants in the educational process using the Scale of psychological well-being questionnaire developed by C. D. Ryff and adapted to the educational context in order to determine the psychological safety of the proposed pedagogical methodology;
- to compare self-reported estimates of student progress between the selected disciplines.

2 Methods and materials

2.1 Research design

In the context of the restrictions caused by the pandemic, the educational process in higher educational institutions of Kazakhstan and the Russian Federation in 2020–2021 was implemented online. In this regard, there was a need to develop innovative teaching methods for their further implementation in online training courses. The authors developed an innovative methodology for teaching disciplines of natural science and mathematics. It builds on the concepts of active social learning and integrates modern approaches from STEM education and Content and Language Integrated Learning (CLIL). These include the constructivist, problem-oriented, project-based and research approaches. The proposed methodology has been

adapted to the implementation of educational activities in an online learning environment (Fig. 1).

In pedagogical practice, the implementation of pedagogical teaching methods is carried out using the innovative capabilities of digital technologies, such as LMC learning management systems, online communication services, specialized mobile applications, as well as immersive AR / VR / XR technologies. The educational content that fills the educational course is developed with the aim of updating knowledge and its application in practice and directs the student to the stable development of professional competencies and teamwork skills in the process of active
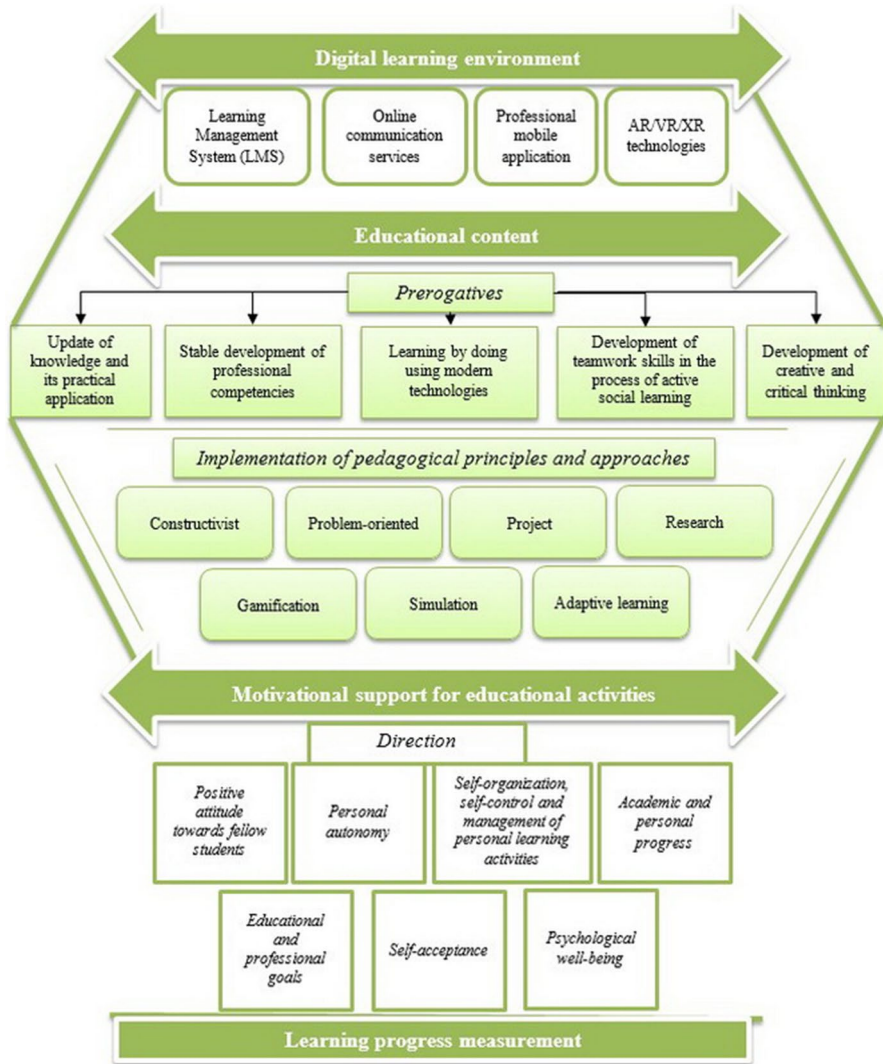

Fig. 1 Pedagogical Methods of Teaching Natural and Mathematical Sciences. * own development

social learning, the development of creative, critical thinking and digital literacy. The introduction of a pedagogical model for teaching natural and mathematical sciences involves the implementation of such pedagogical principles as: adaptive learning, modeling and imitation, gamification, as well as constructivist, problem-oriented, project, research approaches. Motivational support for educational activities in the process of implementing pedagogical methods in practice is an effective tool for achieving educational goals, by creating conditions for personal autonomy, educational and personal progress, self-organization, self-control and management of personal learning activities, supporting a positive attitude towards colleagues in training, psychological well-being and self-acceptance.

The innovative methodology was tested from January 2020 to June 2021 as part of the study of Molecular Biology and Mathematical Analysis. The educational experiment involved 80 students: 40 students in the [BLINDED] University and 40 students in the [BLINDED] University (Table 1).

The innovative pedagogical model was tested within the framework of two educational courses Molecular Biology and Mathematical Analysis, which, according to the moderators, made it possible to more contrastly determine its adaptability to different educational content of the natural and mathematical sciences.

The Mathematics Teaching course, combined with the CLIL technology, aims to deliver the fundamental knowledge by offering students some crucial practical and theoretical problems to solve. These problems refer to various areas of mathematics that are taught at school. The primary objectives of the course are to help students develop logical thinking and teach them the basic methods of analysis and modeling. In CLIL methodology, language appears as a tool for learning other subjects and developing the abilities to rethink the learning process, engage others, and instill communicative competencies. CLIL seeks to make teacher students proficient with innovative teaching methods in the classroom. The technology involves the independent learning of content (video lectures, tests and electronic documents) in an e-learning environment and practical assignments. The course was delivered in English.

The Mathematics Teaching course was tested on 40 students in the [BLINDED] University. It was developed using Matematica, WolframAlpha, Photomath, BuzzMath, and ACT Math: Data Analysis.

The Molecular Biology course is one of the basic training courses as it introduces the main concepts that modern biology is based on. Students acquire knowledge about biopolymer structure, units, and functions, as well the basic principles of coding, storage and implementation of genetic information, the

Table 1 Participants in the educational experiment

Number of students	Age	Gender	University
40	22–26	M-17, F-13	[BLINDED] University
40	21–23	M-23, F-17	[BLINDED] University

* own development

structure and function of genes and genomes. This course reveals the content, theoretical and practical problems of molecular biology as a science about the structural features and properties of molecules that ensure the existence of a biological form of the motion of matter, as well as its place and role in the group of sciences that make up modern physicochemical biology. The experiment based on the Molecular Biology course was attended by 40 students of [BLINDED] University. Individual practical tasks for students studying Molecular Biology were developed with the help of mobile applications such as Genetics and Molecular Biology; Molecular Methods; WebMO Molecule Editor; Molecular Biology Quiz / MCQsLearn; Molecular Biology MCQ.

The three disciplines were taught based on similar procedures in order to determine such characteristics of an innovative pedagogical model as universality and adaptability to different educational programs. The courses were divided into 10 thematic modules. Within the framework of each course, lectures were delivered with the help of the online meeting software Microsoft Teams (Microsoft, 2021). The curators of the courses gave 10 online lectures with the provision of access to a multimedia educational resource. To ensure the acquisition of knowledge and the development of students' awareness of its practical application, a channel was created on the Telegram social network. Thus, the curators of the courses posted information on modern achievements in the field of molecular biology and mathematical analysis.

The tasks were developed and distributed within team projects with the help of the Teamer management system (Teamer, 2021), which ensured the coverage of a number of assignments on one platform, the connection of each task with instructions, as well as group project activities clearly scheduled and timed. The service allowed the teachers to track the progress of each student in real-time. Teamer includes three sections: 'What to do?' (educational tasks), 'Who is to blame?' (to-do calendar) and 'Where is everyone?' (database of the project group participants). Using the platform, the course curators planned the schedule and the order of assignments, as well as implemented group project-based activities.

To ensure communication between the participants in the educational experiment and motivation for educational activities, a group was created on Facebook. The course curator developed digital motivational learning content, which included video, audio, images, and quizzes conceptually based on the theory of positive psychology and psychological well-being. The social interaction of students in the learning process was observed by a representative of the Center for Coordination of Educational Projects of [BLINDED] University.

The structure of educational activities is presented in Fig. 2.

In order to determine the psychological safety of the proposed model, the level of psychological well-being of the participants in the educational process was assessed using the Scale of psychological well-being questionnaire developed by Ryff (1995) and adapted to the educational context by the course curators. This questionnaire consisted of 84 items and included 6 scales and an integral indicator of psychological well-being of the participants in the educational process.

The study participants were surveyed twice—at the end of the first month of training and at the beginning of the last one—in order to study changes in the
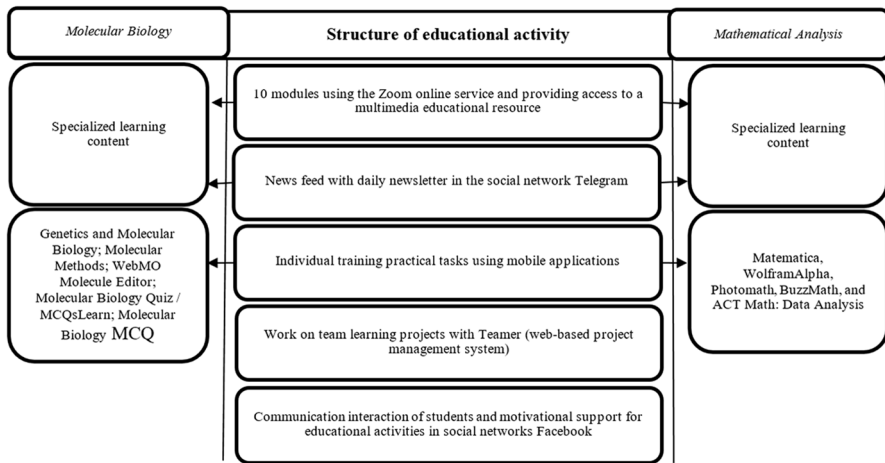
Molecular Biology	Structure of educational activity	Mathematical Analysis
Specialized learning content	10 modules using the Zoom online service and providing access to a multimedia educational resource	Specialized learning content
	News feed with daily newsletter in the social network Telegram	
Genetics and Molecular Biology; Molecular Methods; WebMO Molecule Editor; Molecular Biology Quiz / MCQsLearn; Molecular Biology MCQ	Individual training practical tasks using mobile applications	Matematica, WolframAlpha, Photomath, BuzzMath, and ACT Math: Data Analysis
	Work on team learning projects with Teamer (web-based project management system)	
	Communication interaction of students and motivational support for educational activities in social networks Facebook	

Fig. 2 The structure of educational activities. * own development

indicators of psychological well-being under the influence of the proposed teaching methodology.

The students were given a list of statements related to their feelings about themselves and their learning. They were asked to circle the number that best reflected the degree of their agreement/disagreement with each statement (Table 2).

The statements are assigned points equal to the numerical value of the answer in the answer sheet. Some of the items are interpreted as reverse values (Table 3).

2.2 Ethical issues

Before the survey, the participants familiarized themselves with the goals and objectives of the study and provided written consent to participate in the educational experiment. All participants were informed that there would be no reward or punishment for their participation or refusal.

2.3 Data analysis

The Survio service (Survio, 2021) was used to create the questionnaire and process the data obtained. Survio is an efficient solution for making questionnaires, collecting and analyzing data, and sharing the results obtained. The results were assessed both with reference to each participant in order to determine the attitude and educational intentions of the student and in the context of the group while involving the calculation of average values, which were used to study the influence of the pedagogical methodology being tested on the change in the indicators under consideration.

Due to the small size and structure of the sample, the data obtained are preliminary and superficial and have not been generalized. Further quantitative studies with

Table 2 Questionnaire for assessing the psychological well-being of the participants in the educational experiment

No	Statement	Assessment					
		Strongly disagree	Disagree	Rather disagree	Rather agree	Agree	Absolutely agree
1	The majority of my peers describe me as a good and diligent student	1	2	3	4	5	6
2	Sometimes I change my behavior in class or my way of thinking in order not to stand apart in the group	1	2	3	4	5	6
3	As a rule, I consider myself responsible for the way I learn	1	2	3	4	5	6
4	I am not interested in the activities that provide long-term results or those that I do not use in my daily life	1	2	3	4	5	6
5	I enjoy thinking about my past and future academic achievements	1	2	3	4	5	6
6	I like to investigate the field of knowledge that I've chosen	1	2	3	4	5	6
7	I find it difficult and frustrating to maintain group interactions in the learning process	1	2	3	4	5	6
8	I am not afraid to voice my opinion even when it contradicts the opinion of the majority of my fellow students	1	2	3	4	5	6
9	The requirements of everyday learning activities often depress me	1	2	3	4	5	6
10	In fact, I believe that over time I will reveal my potential to a greater extent	1	2	3	4	5	6
11	I am focused on my current assignments and do not think about the strategic goals of training	1	2	3	4	5	6
12	Generally, I am a self-confident student	1	2	3	4	5	6
13	I often lack peer support and I have few friends with whom I can share my learning problems and ideas	1	2	3	4	5	6
14	In the process of completing educational assignments, my decisions are rarely affected by what other students do and think	1	2	3	4	5	6
15	I don't really fit into the study group	1	2	3	4	5	6
16	I am one of those students who like to try new things and experiment	1	2	3	4	5	6
17	I try to focus on my learning activities in real-time and I am anxious about future assignments	1	2	3	4	5	6
18	It seems to me that many of my peers have better learning outcomes than me	1	2	3	4	5	6
19	I enjoy communicating with peers, I am an active communicator	1	2	3	4	5	6

Table 2 (continued)

No	Statement	Assessment					
		Strongly disagree	Disagree	Rather disagree	Rather agree	Agree	Absolutely agree
20	I am concerned about what other students think of me	1	2	3	4	5	6
21	I can handle my daily educational assignments quite well	1	2	3	4	5	6
22	I do not need to search for new educational opportunities, I am satisfied with my training	1	2	3	4	5	6
23	My learning activity makes sense	1	2	3	4	5	6
24	If I had an opportunity, I would change many things about myself	1	2	3	4	5	6
25	I find it important to be a good listener when other students share their views, problems and ideas	1	2	3	4	5	6
26	It is more important for me to be at peace with myself and objectively assess my educational achievements than get the approval and praise of others	1	2	3	4	5	6
27	I often feel that my academic responsibilities depress me	1	2	3	4	5	6
28	It seems to me that a new learning experience that can expand knowledge about my own self and the world around is very important	1	2	3	4	5	6
29	My routine learning activities often seem trivial and insignificant to me	1	2	3	4	5	6
30	Generally, I like myself	1	2	3	4	5	6
31	There are few students who are ready to listen to me and talk to me	1	2	3	4	5	6
32	I often study authoritative opinions which I usually follow	1	2	3	4	5	6
33	In case of my failure in the learning process, I will take effective measures to change the situation	1	2	3	4	5	6
34	I have not improved my skills much in the process of learning	1	2	3	4	5	6
35	I am not very well aware of what results learning will provide me with	1	2	3	4	5	6
36	I often make mistakes in educational assignments, but it's all to the good. I am just learning	1	2	3	4	5	6
37	I believe I benefit a lot from learning interactions with other students	1	2	3	4	5	6
38	Other students rarely manage to persuade me to do things that I don't want to do	1	2	3	4	5	6
39	I cope pretty well with my academic responsibilities	1	2	3	4	5	6

Table 2 (continued)

No	Statement	Assessment					
		Strongly disagree	Disagree	Rather disagree	Rather agree	Agree	Absolutely agree
40	In my opinion, a person is capable of learning at any age	1	2	3	4	5	6
41	I used to set myself learning goals, but now it seems to me ineffective and a waste of time	1	2	3	4	5	6
42	I am largely disappointed with my academic achievements	1	2	3	4	5	6
43	It seems to me that other students have more fun and dynamic group learning than me	1	2	3	4	5	6
44	It is more important for me to join and adapt to a study group than to work on a project on my own	1	2	3	4	5	6
45	I get upset when I don't have time to do everything that has been scheduled for the day	1	2	3	4	5	6
46	Over time, I began to better understand the disciplines I study, and this has made me more competitive and competent	1	2	3	4	5	6
47	I enjoy developing and implementing learning plans	1	2	3	4	5	6
48	As a rule, I am proud of myself and my manifestations in educational activities	1	2	3	4	5	6
49	Other students see me as a responsive learning partner who always has time to address collective learning issues	1	2	3	4	5	6
50	I am confident in my judgments even when they are contrary to the opinions of other students	1	2	3	4	5	6
51	I can manage my time so that all educational assignments are completed before the deadline	1	2	3	4	5	6
52	I feel that in the process of learning I have become better	1	2	3	4	5	6
53	I actively try to implement the learning plans I make for myself	1	2	3	4	5	6
54	Sometimes I envy the success of other students	1	2	3	4	5	6
55	I had few effective and trusting relationships with other students of the group	1	2	3	4	5	6
56	I find it difficult to express my opinion during educational discussions	1	2	3	4	5	6
57	I enjoy the fact that I can cope with my academic duties	1	2	3	4	5	6
58	It is difficult for me to adapt to the new formats of educational activities when I have to change my usual behavior	1	2	3	4	5	6

Table 2 (continued)

No	Statement	Assessment					
		Strongly disagree	Disagree	Rather disagree	Rather agree	Agree	Absolutely agree
59	I am not one of those students who take classes with no intent	1	2	3	4	5	6
60	Perhaps I underestimate my capabilities and treat myself worse than most of the students in the group	1	2	3	4	5	6
61	When it comes to group learning assignments, I often feel an outsider	1	2	3	4	5	6
62	I often change my point of view if other students disagree with it	1	2	3	4	5	6
63	I do not like to make learning plans for the day as I never manage to do everything planned	1	2	3	4	5	6
64	I believe that learning is a continuous process of cognition and development	1	2	3	4	5	6
65	Sometimes it seems to me that I have already learned everything I could	1	2	3	4	5	6
66	I often think that I have a bad learning style	1	2	3	4	5	6
67	I know I can trust other students and they know that they can trust me	1	2	3	4	5	6
68	I am not one of those who succumb to the pressure of society determining the way of thinking and behavior	1	2	3	4	5	6
69	I managed to find a course to my liking and form the relationships I needed in the group	1	2	3	4	5	6
70	I like the fact that in the process of learning my views have changed and become more mature	1	2	3	4	5	6
71	The learning goals I set myself were more likely to bring me good results rather than disappointment	1	2	3	4	5	6
72	In my learning experience, there were ups and downs, but this was necessary	1	2	3	4	5	6
73	I find it difficult to fully reveal my skills in teamwork with other students	1	2	3	4	5	6
74	I am concerned about the assessment of my performance in teamwork by other students	1	2	3	4	5	6
75	I find it difficult to manage my learning activities in the way I want	1	2	3	4	5	6
76	I am not trying to change or improve my approach to learning	1	2	3	4	5	6
77	I am pleased to think about my learning achievements	1	2	3	4	5	6
78	When I compare myself with other students, I realize that in many ways I am better than them	1	2	3	4	5	6
79	In the study group, we support and try to help each other	1	2	3	4	5	6

Table 2 (continued)

No	Statement	Assessment					
		Strongly disagree	Disagree	Rather disagree	Rather agree	Agree	Absolutely agree
80	I judge myself based on what I think is important rather than what others think is important	1	2	3	4	5	6
81	I managed to create a comfortable learning atmosphere for myself	1	2	3	4	5	6
82	I find it difficult to accept changes and innovations in learning activities	1	2	3	4	5	6
83	I don't think I should expect anything from learning	1	2	3	4	5	6
84	No one is perfect, but I have more drawbacks than other people	1	2	3	4	5	6

[*]adapted based on the Psychological Well-Being Scale, PWB (Ryff, 1995)

Table 3 Calculation of questionnaire points

Answer	Direct values	Reverse values
Strongly disagree	1 point	6 points
Disagree	6 points	5 points
Rather disagree	3 points	4 points
Rather agree	4 points	3 points
Agree	5 points	6 points
Absolutely agree	6 points	1 point

Scale	Direct statements	Reverse statements
Positive attitude towards fellow students	1, 19, 25, 37, 49, 67, 79	7, 13, 31, 43, 55, 61, 73
Personal autonomy	8, 14, 26, 38, 50, 68, 80	2, 20, 32, 44, 56, 62, 74
Self-organization, self-control and management of personal learning activities	3, 21, 33, 39, 51, 57, 69, 81	9, 15, 27, 45, 63, 75
Academic and personal progress	10, 16, 28, 40, 46, 52, 64, 70	4, 22, 34, 58, 76, 82
Academic and professional goals	5, 23, 47, 53, 59, 71, 77	11, 17, 29, 35, 41, 65, 83
Self-acceptance	6, 12, 30, 36, 48, 72, 78	18, 24, 42, 54, 60, 66, 84
Psychological well-being	1, 3, 5, 6, 8, 10, 12, 14, 16, 19, 21, 23, 25, 26, 28, 30, 33, 36, 37, 38, 39, 40, 46, 47, 48, 49, 50, 51, 52, 53, 57, 59, 64, 67, 68, 69, 70, 72, 71, 77, 78, 79, 80, 81 0–323 points—a low level of psychological well-being; 324–353 points—an average level of psychological well-being; 354 and more points—a high level of psychological well-being;	2, 4, 7, 9, 11, 13, 15, 17, 20, 22, 27, 29, 31, 32, 34, 35, 18, 24, 41, 42, 43, 44, 45, 54, 55, 56, 58, 60, 61, 62, 63, 65, 66, 73, 74, 75, 76, 82, 83, 84

* adapted based on the Psychological Well-Being Scale, PWB (Ryff, 1995)

a larger and more balanced sample are needed to identify the impact of the proposed methodology on the effectiveness of educational activities.

3 Results

The proposed pedagogical model focuses on the applied nature of learning in the context of the possibilities of the digital space and motivational support for the participants in the educational process. The prerogatives of practical educational activities are the update of knowledge and its application in practice; stable development of professional competencies; learning by doing using modern technologies; development of teamwork skills in the process of active social learning; development of creative and critical thinking.

In the course of studying Molecular Biology, the students had an opportunity to familiarize themselves with scientific information about various molecular methods that are currently used in molecular laboratories, perform interactive tasks and assess their knowledge by participating in exciting quizzes. The functionality of the mobile applications given in the course promoted applied and fun learning. The Genetics and Molecular Biology app (AJAX MEDIA TECH PRIVATE LIMITED) made it easy and fun for the students to learn molecular biology by visualizing colorful images and videos. The WebMO Molecule Editor (WebMO, LLC) application allowed students to create and view molecules in three-dimensional space, visualize orbitals and symmetry elements, search for chemical information and properties in external databases, and access modern computational chemistry programs. The Molecular Biology Quiz / MCQsLearn (Molecular Biology Trivia Quiz) application provided learners with an opportunity to test their knowledge in the field of molecular biology based on more than 600+ questions related to bioinformatics; biological membranes, biotechnology and recombinant DNA; replication, recombination and DNA repair; free radicals and antioxidants; genetics, immunology; the human genome project; insulin and glucose homeostasis; xenobiotic metabolism; prostaglandins and related compounds; the regulation of gene expression; biochemistry tools. To assess knowledge, the Molecular Biology MCQ (RajalakshmiRTY) application containing more than 10,000 questions was used.

Students enrolled in the Mathematics Teaching course could learn the basic concepts and methods used in the Theory of Limits and innovative methods of teaching mathematics at school using the CLIL technique. The software solutions considered within the course were Mathway, Microsoft Maths Solver, Brainly, Mathematical Analysis, WolframAlpha, Photomath, BuzzMath, and ACT Math: Data Analysis. When performing the practical tasks, students determined the possibilities of applying theorems and methods of mathematical analysis to formulate and solve applied problems. They also calculated the limits of functions, performed differentiation and integration, calculated integrals, for expanded functions into series in English.

In the proposed pedagogical methodology, motivational support is carried out in the field of the formation and promotion of a positive attitude towards fellow students; the development of personal autonomy; the improvement of the skills of self-organization, self-control and management of personal learning activities; the

Table 4 The results of the survey at the beginning and end of the course Molecular Biology

Indicator	Average (points)	Start of educational practice	End of educational practice	Deviation of indicators (- / +)
Positive attitude towards fellow students	63	49	58	+9
Personal autonomy	56	50	58	+8
Self-organization, self-control and management of personal learning activities	57	47	56	+9
Academic and personal progress	65	56	68	+12
Academic and professional goals	63	54	67	+13
Self-acceptance	59	48	61	+13
Psychological well-being	363	346	369	+23

[*] own development

Table 5 The results of the survey at the beginning and end of the course The Mathematics Teaching

Indicator	Average (points)	Start of educational practice	End of educational practice	Deviation of indicators (- / +)
Positive attitude towards fellow students	63	41	45	+4
Personal autonomy	56	55	67	+12
Self-organization, self-control and management of personal learning activities	57	45	57	+12
Academic and personal progress	65	53	62	+9
Academic and professional goals	63	59	66	+7
Self-acceptance	59	51	60	+9
Psychological well-being	363	345	363	+18

[*] own development

achievement of educational and personal progress; the development of technology literacy in setting educational and professional goals; support for psychological well-being and self-acceptance.

In order to ensure a personalized approach to learning and measure the degree of safety of the tested teaching methodology, at the beginning and at the end of training, the level of psychological well-being of the participants in the educational process was investigated. The results from the assessment of the psychological well-being of students engaged in Molecular Biology (Tables 4 and 5) and Mathematics Teaching are described based on the analysis of the priority of beliefs.

The Cronbach Alpha test was used to determine the reliability and internal consistency of the assessment method used, as well as the reliability of students' self-assessment. The study of the results of the survey of Cronbach Alpha methods

showed a high internal consistency of the characteristics describing the studied object ($\alpha = 0.751$). This result allows the descriptive statistics to be judged to be more representative.

Based on the results of the survey, it can be concluded that the educational practice offered by the course had a positive impact on the level of psychological well-being of the participants.

The level of positive attitude towards each other among the participants in the Molecular Biology course increased by nine points and by 4 points among the participants in the Mathematics Teaching course. This indicates that the applied pedagogical methodology contributed to the formation of effective and trusting interpersonal relationships in the group and promoted a proactive corporate culture allowing each participant to demonstrate their communication abilities, as well as to develop the skills of mutual assistance and support in group work.

The indicator of personal autonomy increased by eight points among the participants in the Molecular Biology course and by 12 points among the participants in the Mathematics Teaching course, which indicates that the teaching methodology contributed to the development of students' skills of independent learning, self-organization, responsible decision-making and the ability to critically assess their educational achievements in accordance with personal criteria.

In the process of learning, students studying Molecular Biology and Mathematics Teaching improved their skills of self-organization, self-control, and management of personal learning activities, on average, by 9 and 12 points, respectively. This testifies to the students' adaptation to digital pedagogy and acceptance of distance learning, mastery of the skills of learning activity management, and the effective use of the technological capabilities provided by the course.

The indicator of academic and personal progress, on average, increased by 12 points in the Molecular Biology group and by 9 points in the Mathematics Teaching group. This indicates that the pedagogical methodology tested in the training courses has demonstrated its effectiveness in the development of the professional and personal competencies of students and they started to consider themselves as self-actualizing individuals open to new knowledge and experience while revealing and realizing their potential to the fullest. The students showed a high level of mastery of the educational material, which was also evidenced by the results of the tests taken after each unit completion.

The students enrolled in the Molecular Biology course demonstrated an improvement in the skills of setting educational and professional goals, as evidenced by an increase in the indicator by 13 points. The students studying Mathematics Teaching improved their goal setting skills by 7 points.

The self-acceptance indicator, on average, increased by 13 points among the students studying Molecular Biology and by 9 points among the students enrolled in the Mathematics Teaching course, which indicates that educational activity influenced the positive self-esteem of the course participants by developing their ability to critically evaluate their own good and bad qualities and be congruent in group learning interactions.

The complex indicator of the psychological well-being of the participants in the educational experiment increased by 23 points among the students enrolled in the

Molecular Biology course and by 18 points among the students studying Mathematics Teaching, which indicates that the proposed pedagogical methodology has demonstrated its safety in relation to the life processes of students, improved their perception of learning and themselves in the role of its participant, promoted positive self-esteem in group learning contacts, and by developing learning involvement and interest through the Clil approaches, qualitatively contributed to the achievement of educational progress by each student.

Figure 3 shows the personal progress of the students enrolled in the two courses mentioned above and trained in accordance with the innovative pedagogical methods of teaching natural and mathematical sciences based on the results of their self-analysis.

The results of testing the pedagogical model confirmed its versatility and adaptability to various types of educational content.

4 Discussion

Currently, students need both cognitive and practical learning experiences (Abramovich et al., 2019). In order to ensure an effective and efficient learning process, teachers should connect the educational content to everyday life and provide students with real examples and applications so that they can interact with the teacher, the educational material and the learning environment, as well as understand the importance of the discipline being studied (Algani, 2019). The learning environment in higher educational institutions, especially in the context of natural and mathematical sciences, requires deep learning supported by critical thinking and introspection (Santangelo et al., 2021), which fosters creativity and innovation (Khotimah et al., 2021). A rational and radical approach to the study of natural and mathematical disciplines draws attention to interdisciplinary interaction (Khirwadkar et al., 2020). In the learning process, students must think, solve problems, change their positions and opinions, develop skills and accumulate knowledge. The application of several
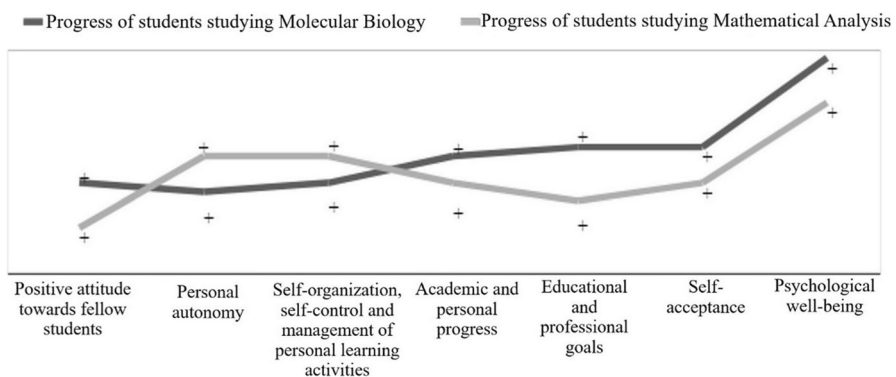

Fig. 3 Students' assessment of their own progress based on the learning outcomes of the courses. * own development

pedagogical principles based on a constructivist paradigm can lead to good learning outcomes. The application of constructivist teaching methods is one of the cornerstones of science and technology and, in fact, represents the interaction between physical and cognitive activities (Algani, 2019). According to the constructivist theory, learning is an active process allowing students to construct knowledge (Allcoat et al., 2021). The STEM approach is closely related to the CBL approach, which encourages students to seek solutions to real-world problems using available digital tools (Leijon et al., 2021). Another approach that is prioritized in the STEM paradigm is project-based learning. The implementation of educational projects involves the creation of a subjectively new personally significant product focused on the formation of deep knowledge and meta-subject abilities, the development of independence, and increased interest in the studied subject (Luneeva & Zakirova, 2017).

E-learning methods violate the stereotypes of teaching and learning processes by making it possible to teach and study regardless of location and time (Moreno-Guerrero et al., 2020). Technology integration enables educators to create learning experiences that actively and meaningfully engage students in the course content (Borba, 2021). Technology can significantly influence student attitudes and behavior, as well as increase their engagement and motivation (Novita & Herman, 2021). Most of the online learning platform models are based on constructivist theories with an emphasis on fundamental design elements, collaboration elements, self-assessment, team assessment, and facilitator assessment. This type of learning environment is an integration of technology, content and people providing learning, social and technical support in achieving goals and learning objectives (Iji & Abah, 2018). Due to the fact that social and interactive participation is an integral part of cognitive development, learning settings that are most conducive to interactive learning should be investigated (Wannapiroon et al., 2021). In addition, it becomes apparent that there is a need for greater exchange and interdisciplinary collaboration between teachers (Fan, 2021).

The introduction of network technologies, cloud services, big data, as well as virtual and augmented reality in teaching practice dramatically increases learning opportunities (Liu et al., 2020). For example, virtual reality (VR) is a technological tool of display that allows users to be placed in a virtual world where situations that would otherwise be difficult to imagine in real life can be created (Hsu, 2021), and augmented reality (AR) provides real-time interaction while combining the virtual and the real worlds (Çetin & Türkan, 2021). The AR learning environment not only enhances knowledge but also provides students with an opportunity to gain an advanced level of learning experience in distance learning during the pandemic (Eldokhny & Drwish, 2021). AR introduces important specifics in the professional activities of teachers and in the transformation of the content of education (Soroko, 2021). A higher level of involvement in the educational process can lead to a more holistic understanding of the learning content and also help in the endogenization or internalization of knowledge (Cai et al., 2019). Virtual and augmented technologies (VAR) are at the early stages of implementation as learning platforms in higher education. The rate of implementation of VAR technology in higher education is associated with the teacher's ability to experiment with the educational content of VAR (Marks & Thomas, 2021). In recent years, there has been a shift towards the

integration of digital capabilities across specific contexts and/or learning environments while creating a "continuum" of mixed reality (MR) digital experiences based on a combination of different technologies, tools, platforms, and capabilities, as well as providing learning methods not otherwise available along with a more hands-on, immersive and proactive approach to teaching and learning (Allcoat et al., 2021).

This is consistent with the opinion that modern digital technologies make it possible to simulate various professional scenarios and environments that are difficult to demonstrate in physical space. In this regard, educational strategies should be developed taking into account the variety of online services, platforms, and mobile applications that are in the public domain and allow users to make their learning meaningful and practical, as well as to reveal the understanding of the importance of educational activities in the life of a modern person (Yıldırım, 2021).

In our opinion, an effective pedagogical methodology, embedded in the course, is a key to the academic progress of each student. In the current educational practice, STEM learning is gaining popularity and taking root in learning trajectories (Liu et al., 2020). Analyzing the interdisciplinary experience of teaching science and mathematics in higher education focused on research-based learning, 6E learning models, and the use of the innovative learning environment of CreativeLab_Sci & Math created by the Department of Mathematical and Natural Sciences of the Polytechnic Institute of Santarem (Portugal), researchers concluded that student participation in integrative learning contributes to the formation of a less fragmented view of science and mathematics education. The integration of science and mathematics teaching allows students to develop engagement, critical and creative thinking, reasoning and problem-solving skills while fostering deeper conceptual understanding of both subjects (Mestrinho & Cavadas, 2018). However, it should be considered that pedagogical transformations depend not only on the intellectual progressiveness of educational institutions but also on the progressiveness of society (Deák et al., 2021).

Although the impact of the pandemic shocked educators at all levels, the emergency also inspired them to search for the solutions to problems they had not faced before (Aldon et al., 2021). A variety of ideas and discussions about the role of educational technologies and changes in the needs of students put forward the importance and priority of innovative solutions in modern pedagogy (Gilbert et al., 2021). Scientists are currently assessing the effectiveness of the global changes in the education system and are trying to find out whether their efforts to create new or adapted learning methods have had a positive impact on students and on the educational process (Jackson, 2021).

5 Conclusions

Among the modern trends in educational activities, innovative teaching methods and technologies dominate; they can have a qualitative influence on the effectiveness and efficiency of teaching. An innovative pedagogical methodology with an emphasis on the applied nature of learning in the context of the possibilities of the digital space and with the use of motivational support for the participants in

the educational process has been described. As part of the pedagogical methodology, online learning is implemented with the help of a learning management system, online communication services, professional mobile applications and AR / VR / XR immersion technologies, Clil technology. The prerogatives of practical educational activities are the update of knowledge and its application in practice; stable development of professional competencies; learning by doing using modern technologies; development of teamwork skills in the process of active social learning; development of creative and critical thinking. In the course of educational activities, the following principles should be implemented: constructivist, problem-oriented, project and research approaches, as well as pedagogical approaches of gamification, simulation, and adaptive learning. In the proposed pedagogical methodology, motivational support is carried out in the field of the formation and promotion of a positive attitude towards fellow students; the development of personal autonomy; the improvement of the skills of self-organization, self-control and management of personal learning activities; the achievement of educational and personal progress; the development of technology literacy in setting educational and professional goals; support for psychological well-being and self-acceptance.

The developed methodology was proven effective in Mathematics Teaching and Molecular Biology classrooms. It qualitatively contributed to the formation of effective and trusting interpersonal relationships in the group and promoted a proactive corporate culture allowing each participant to demonstrate their communication abilities, as well as to develop the skills of mutual assistance and support in group work. The courses allowed students to improve their skills of independent learning, self-organization, responsible decision-making and the ability to critically assess their educational achievements in accordance with personal criteria. The students easily adapted to digital pedagogy, mastered the skills of learning activity management, and effectively used the technological opportunities provided by the courses. The students showed a high level of mastery of the educational material, which was also evidenced by the results of the tests taken after each unit completion. The pedagogical methodology contributed to the formation of a sense of purposefulness and meaningful learning in the students; the educational activities influenced the positive self-esteem of the course participants developing their ability to critically assess their good and bad qualities and to be congruent in group learning interactions.

Declarations

Ethics approval The authors declare that the work is written with due consideration of ethical standards. The study was conducted in accordance with the ethical principles approved by the Ethics Committee of E.A. Buketov Karaganda University and Kazan Federal University.

Consent All participants gave their written informed consent.

Competing interests Authors declare that they have no competing interests.

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