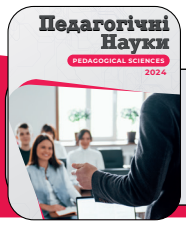

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# Possibilities for integrating the flipped classroom into a bilingual course in higher mathematics at a technical university

**Abstract.** Changes in higher education paradigms and the challenges of globalisation necessitate revising methods and approaches to teaching disciplines in Ukrainian universities. This article aimed to summarise and analyse the practical application of flipped classroom technology in teaching higher mathematics to students specialising in engineering and technical disciplines on a bilingual basis. The study utilised general scientific research methods: theoretical methods (system analysis, comparison, generalisation, synthesis) and empirical methods (pedagogical observation, interviews, professional experience exchange, and analysis of pedagogical activity outcomes). The study examined the stages of flipped classroom technology from a historical perspective and identifies the rationale for employing this methodology under conditions of limited social contact. The advantages of this teaching model for mathematical disciplines taught bilingually were analysed. The essential role of information and communication technologies in implementing the flipped classroom model was elucidated. The authors' experience teaching English-language mathematics courses to prospective engineers using flipped classroom methods in a distance learning context was discussed and thoroughly evaluated. Potential disadvantages of this teaching model were also highlighted. It has been determined that the flipped classroom represents a learning model in which a student-centred approach predominates, significantly enhancing interaction between students and lecturers. This approach fosters greater student engagement and facilitates the acquisition of subject matter in a foreign language. The findings of this study can be applied to the teaching of professional disciplines at technical universities, both in the native language and bilingually

**Keywords:** bilingual education; bilingual teaching/learning; subject-oriented didactic models; mathematical courses; flipped learning; information and communication technologies

## INTRODUCTION

The current stage of development in the Ukrainian education system is characterised by the rapid implementation of innovative processes aimed at its integration into the global educational landscape. Significant changes in pedagogical theory and educational practice focus on harmonising Ukrainian and international educational programmes, enhancing the academic mobility of Ukrainian university students, and ensuring the international recognition of domestic higher education qualifications. In this context, it is crucial to prepare specialists who not only

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possess modern knowledge but can also apply it effectively in practical work within a globalised environment, including proficiency in documentation and communication in foreign languages. Consequently, the adoption of bilingual education has become increasingly relevant. Bilingual education enables a foreign language, alongside the native language, to function as a tool for learning, self-education, intercultural communication, and fostering multicultural awareness. One significant aspect of modernising higher education involves the integration of bilingual teaching and learning into professional university training. Bilingual education entails delivering professional disciplines in a foreign language, which serves as a medium for exploring various subject areas. This study focuses on disciplines within the mathematical cycle, which are foundational for students specialising in engineering and technical fields.

The education sector, like all areas of public life, has faced significant changes and challenges. The WHO declared the spread of coronavirus infection a pandemic, leading to recommendations to limit social contact and shift learning from physical classrooms to virtual ones. This relocation of learning environments has accelerated the adoption of information and communication technologies in higher education, providing an alternative means of acquiring and disseminating knowledge during a critical period of human development. The latest generation of state educational standards optimises the learning process by incorporating distance learning, which aims to enhance educational quality, promote students' information mobility, and foster their capacity for self-directed learning. This shift in educational paradigms is reflected in Ukrainian legislation (Resolution of the Cabinet of Ministers of Ukraine No. 896, 1993; Decree of the President of Ukraine No. 347/2002, 2002).

New educational standards can be implemented within the framework of the so-called flipped classroom (FC). This teaching model was introduced in the United States in the early 2000s, with chemistry teachers Jonathan Bergmann and Aaron Sams recognised as its founders (Bergmann & Sams, 2012; Siegle, 2014).. These educators provided their students, who frequently missed classes, with recorded lectures to help them address gaps in their knowledge. Their initiatives formed the foundation for the development of a new educational programme. In the spring of 2007, Bergmann and Sams used PowerPoint to create several slideshows with voiceovers and text notes. They converted these into video files that were distributed online, allowing students to access the materials at their convenience. This methodological innovation attracted the interest of colleagues from other disciplines and was subsequently adapted for foreign language classes and other courses. The practices developed by Bergmann and Sams extended beyond the United States and were tested by educators in other countries. The flipped classroom is a hybrid strategy that divides learning into two distinct phases, in contrast to traditional teaching approaches. During the first phase, conducted remotely, students independently study learning materials and resources. The second phase occurs in either an online or physical classroom, where teachers and students engage in discussions and collaborate on group projects. Additionally, FC is typically supported by an educational platform that integrates various digital learning and assessment tools. This platform serves as a centralised hub for teachers to provide assignments, interactive content, and learning resources. It also enables them to monitor students' progress and facilitate communication. Overall, FC leverages digital tools and platforms to combine in-person and virtual instruction, thereby enhancing learning quality and fostering student engagement.

This technique has become widespread globally. It is regarded as an evolution of pedagogical approaches that enable lecturers and professors to align their teaching practices with the demands of the digital age. Today's students have grown up surrounded by a multitude of online resources and technological devices, and FC aims to utilise these resources effectively. Among the numerous studies on FC technology, several notable research studies stand out. Research indicates that the advantages of FC technology outweigh those of traditional teaching methods (Beatty *et al.*, 2019). Some studies describe how traditional, passive classes have been transformed into active and individualised learning environments (Goedhart *et al.*, 2019). FC is viewed as a methodology that allows students to learn at their own pace before attending classes and facilitates collaborative interactions and dynamic classroom engagement (Chen *et al.*, 2019; Lo & Hew, 2020). Research by M.Y. Doo & C.J. Bonk (2020) demonstrates that FC is associated with higher levels of student engagement and interest in the subject, as well as increased opportunities for student-centred learning. The integration of FC with problem-based learning has also been explored (Oliván-Blázquez *et al.*, 2022). However, these studies primarily focus on the application of FC technology in settings where students study in their native language rather than a foreign language.

Few studies investigate the use of FC technology in bilingual education at universities. For instance, a modified bilingual flipped learning approach was developed for training international nurses in Finland. This method, which emphasised independence and teamwork, involved dynamic in-class activities and pre-class content, enhancing communication, decision-making, and language proficiency (Cubelo, 2023). Another study examined the usefulness of FC compared to traditional methodologies in training primary school teachers in bilingual classrooms. It analysed students' perceptions of teaching approaches employed in their classrooms and studied during their teacher preparation (Torres, 2022). It is essential to transition students' learning styles from passive acceptance to active engagement through flipped classroom teaching, thereby improving learning outcomes. For example, recommendations for implementing the FC teaching model in bilingual courses on international business negotiation were provided (Zhang *et al.*, 2022). Similarly,

FC teaching modes have been applied in teaching reforms for training applied talents (Jianghong *et al*., 2021). Traditional bilingual teaching methods in International Business Management were found to require improvement, and FC was used as an alternative (Bian, 2021). There is a lack of research on the implementation of FC in bilingual engineering and technical courses, particularly in bilingual mathematics courses.

The purpose of this research was to summarise and analyse the practical application of flipped classroom technology in teaching higher mathematics to students specialising in engineering and technical disciplines in a bilingual context.

## MATERIALS AND METHODS

The research was conducted at Zaporizhzhia Polytechnic National University (Electrical Engineering Faculty). The concepts of Flipped Learning and Bilingual Teaching were adopted as the theoretical foundation of the study. In the first stage, a review of scientific publications and methodological literature on the topic was conducted. Works from the scientometric databases Scopus and WoS were considered. The search was conducted using the keywords: "blended learning", "inverted class", "flipped learning", "flipped classroom", "bilingual teaching", "subject-oriented didactic models", "higher mathematics", "engineering education", and "information and communication technologies", among others. Additionally, methodological materials relevant to the topic were analysed, including the passport and educational programme of the relevant speciality, as well as curricula for mathematical, general technical, and professional disciplines. Methods of analysis and synthesis were applied in the review of the literature. Special attention was given to the application of FC methodology in bilingual classes. The methods of comparison and classification were used to study the peculiarities of FC for students of various specialities and its application to different disciplines. The second stage of the research involved practical implementation. This consisted of conducting mathematics classes using FC methodology. The research methodology necessitated the implementation of the following elements:

The essence of the *FC methodology*. The FC model is a form of blended learning aimed at integrating new information and communication technologies into the educational process to optimise it and enhance students' motivation. This approach is particularly relevant in distance education, where audio and video materials play a significant role. In this model, the teacher provides students with materials to listen to or watch for preliminary self-study at home. During class sessions (whether online or offline), students discuss the material and tackle more complex practical problems. This constitutes the core principle of the FC concept: new topics are studied independently at home, while activities typically assigned as homework – such as reinforcing and consolidating the topics covered – are completed under the teacher's guidance during class.

*Materials used at the individual stage of FC*. FC is comprehensive and includes presentations, vodcasts, podcasts, and pre-vodcasting. A vodcast is an audio lecture accompanied by video content. It involves engaging with video material and includes various activities such as working with authentic resources, completing tests, and undertaking creative tasks. A podcast is an audio file sent to participants in the educational process, which can be accessed either online or offline. Prevodcasting refers to a teacher's methodological practice that provides an overview of the topic at the start of its study through a vodcast. Of the FC components, vodcasts and presentations are the most convenient to use, as they serve as the primary sources of learning material for students. The video content should not exceed 15 minutes in duration to maintain engagement and focus.

*Auditory stage of FC*. After utilising FC resources, the learning process transitions from the online environment to the classroom for solving practical and theoretical problems, conducting empirical tasks, and consolidating learned material. This stage can be conducted either in person or remotely in a synchronous mode. To assess comprehension of the material, the teacher prepares questionnaires, tests, and written exercises. If a student does not fully understand the material, they have the opportunity to review or listen to it multiple times as needed. Face-to-face (or synchronous distance) classes focus on solving more complex tasks, with the teacher acting as a tutor, guiding students through the learning process.

In the second stage of the research, the primary method was a natural pedagogical experiment, involving the educational process conducted under predetermined parameters. As part of this framework, purposeful pedagogical observation of students' academic performance was carried out, and any challenges encountered were documented. In the third stage of the research, the outcomes of FC implementation within the bilingual mathematics course were evaluated. The exchange of experiences, along with the study and discussion of the results, took place during methodical seminars and meetings of scientific and methodological councils. Methods of systematisation and generalisation were employed to formulate the conclusions of the study.

## RESULTS

Since 2019, the Faculty of Electrical Engineering has formed groups of students for bilingual education, where mathematical, general technical, and professional disciplines are taught in English. The university utilises the Moodle distance learning system as its educational platform. Before the transition to the distance learning format, FC methods were used to introduce and consolidate new subject and grammatical material, provide students with supplementary resources, and conduct tests. With the implementation of online learning, the FC method became a central approach to student engagement. Prior to lessons (typically one week in advance), students receive pre-vodcasting materials prepared by their lecturers. These include lecture presentations with theoretical content, vodcasts,

and video examples of solving standard problems on the topic. As the mathematical material is presented in English, it is deemed essential to provide students with a thesaurus for the topic. This includes a file containing English terminology and speech expressions relevant to the subject matter. Lecturers also provide a brief test to evaluate students' comprehension.

After completing the test, students can assess whether they have adequately mastered the preliminary material. Feedback from lecturers is facilitated through the Moodle electronic learning system. If students encounter difficulties or have questions about the material, these are addressed directly during practical sessions, conducted either face-to-face or online. For instance, in the linear algebra course, the topic "Determinants of Matrices" is introduced. Students are granted access to videos such as "Calculation of Second-Order Determinant" and "Calculation of Third-Order Determinant". A file containing key terminology is also distributed. After reviewing the material, students complete a test comprising theoretical multiple-choice questions on definitions and terminology, a calculation of a second-order determinant with a definitive answer, and an open-ended task requiring the calculation of a third-order determinant. During the practical session, lecturers and students address any queries on the topic, solve more complex problems involving higher-order determinants, and explore applications of determinants in practical scenarios. The content of the podcasts and vodcasts is tailored to the topic and students' specialisations. Videos are a cornerstone of the FC learning experience. For example, in the analytical geometry course, during the study of the topic "Second-Order Surfaces", students receive a link to a video featuring a 3D animation of a surface derived from a second-order equation. Following this, students are tasked with completing a test that matches each surface with its corresponding equation.

When studying the topic "Derivative" in the mathematical analysis course, students are provided with a corresponding podcast. Having mastered the prior topic, students are introduced to new vocabulary, enabling them to answer the questions following the podcast and complete a basic test. For the topic "Calculation of Volumes Using Multiple Integrals", students receive a podcast and a video featuring visualisations of specific three-dimensional shapes. The students are tasked with proposing a method for calculating the volumes of these shapes and presenting their approach orally during class discussions with the lecturer. The class then analyses and evaluates the proposed solutions collectively. In addition to podcasts, authentic English-language video and audio materials on mathematics, such as those available on YouTube channels, are utilised. The goal is not only to help students engage in mathematical dialogue but also to enhance their listening skills in authentic English. Listening skills are developed by initially listening to English in the background to become accustomed to its intonation, followed by adjusting the playback speed using YouTube's speech slowdown feature to suit the listener's level. Subtitles can also be activated in the desired language for better comprehension. For example, in the field theory course, during the study of the topic "Vector Field", students are provided with an authentic English-language video where the lecturer demonstrates and comments on the Oersted experiment, which determines the direction of the magnetic field of a steady current. Similarly, in the probability theory course, when exploring the topic "Conditional Probability", students are shown an authentic English-language video demonstrating the Monty Hall Dilemma.

By employing FC technology, students are required to study new material as homework before the next class session. They watch and listen to the materials at their convenience, revisiting them as often as necessary to comprehend the sections under study. Students are encouraged to take notes, answer questions, prepare topics for in-class discussion, complete tests, or undertake written assignments. Through this process, students not only grasp the subject material but also enhance their English-speaking, listening, and reading abilities, practise using relevant lexical and grammatical structures, and refine their writing skills. It should be noted that teaching mathematics in English presents specific challenges. Typically, the student's English proficiency within a group is uneven. Some students, despite possessing adequate mathematical knowledge, feel insecure in class due to their weaker English skills. These students may refrain from participating in discussions and, as a result, disengage from classroom activities. The FC approach allows such students to prepare for lessons at their own pace, learn vocabulary and speech patterns pertinent to the topic, and prepare their contributions in advance. This preparation helps them gain confidence, perform on par with their peers, and actively participate in class activities.

The positive aspect of the FC approach lies not only in its capacity to combine e-learning with in-person classes but also in the accessibility of educational resources. Students can engage with the material using various mobile devices. These methods are applicable to students across diverse fields, specialisations, and age groups, underscoring the universality of this approach. Another advantage is the integration of additional authentic materials in bilingual learning. The quality of students' independent work is easily assessed, as lecturers can evaluate their grasp of topics during practical lessons based on their preparation through pre-podcasting and podcasting. This methodology is particularly relevant during periods of distance learning, where maintaining students' motivation to study independently becomes crucial, especially in the absence of direct pedagogical guidance. The implementation of FC technology during a pandemic or under martial law addresses several objectives of distance learning:

1. Creating a "virtual" educational environment enriched with presentations, audio and video materials, and interactive tasks, accessible regardless of time and location;

2. Facilitating continuous and summative assessments of students' competencies by offering various forms of final evaluations;

3. Enhancing English language proficiency alongside mathematical skills, thereby promoting spontaneous communication and enabling access to authentic sources of information.

According to state standards, future graduates of higher education institutions are expected to solve professional problems involving modern hardware and software, organise and conduct experimental research, and apply computer modelling using advanced tools and methods. These requirements align well with the FC framework. While it is impractical to entirely replace traditional teaching methods, combining conventional approaches with FC technology proves to be a productive strategy for teaching students.

## DISCUSSION

The standards of the International Society for Technology in Education establish specific requirements for the learning process. For instance, the standards issued in 2016 specify that:

1. Students should have access to technical tools and the ability to adapt learning spaces, irrespective of the location of the educational institution or the students themselves;

2. Understanding the dynamics of learning in diverse settings should align with the use of safe and legal teaching methods and techniques;

3. Critical thinking should serve as a cornerstone for acquiring new knowledge;

4. Theoretical knowledge should connect to practical applications to develop innovative solutions in various scenarios (ISTE, 2016).

These requirements can be effectively implemented through the FC framework. The FC model redefines the traditional learning process: conventional approaches are linear and time-bound, making it difficult to revisit previously covered material. By contrast, FC technology allows students to set their own learning pace. They can review educational videos independently, regardless of external circumstances. Additionally, students can organise video conferences without an lecturer to collaborate and complete tasks collectively. FC also transforms students' roles from passive recipients of knowledge to active participants in its acquisition.

The guiding principle of FC, a hybrid approach, is "homework in class and reading at home". This strategy offers flexibility depending on factors such as activity duration, available resources, students' abilities, and the lecturer's creativity. According to J. Lecocq & M. Lebrun (2016), "any teacher can experiment with it, on a small or large scale". The integration of innovative ICT-based practices has significantly influenced education. In this context, the evolution of the FC methodology in research warrants attention. J. Bergmann & A. Sams (2012), two of the approach's creators, introduced "flipped learning", a more advanced FC model. They observed that, in the traditional FC model, "all students watch the same video on the same night" before completing identical tasks in class. It is crucial to acknowledge that pupils in a group frequently have varying skill levels and aptitudes. This indicates that while some students are on track, others might have trouble understanding ideas or require further time. Students can study "the material at their own pace" using the FC approach. Not every student watches the same film on the same night as a result. Students watch and learn in an asynchronous and differentiated system that aims to have them assimilate and master the material at their own pace".

In their research, Marcel Lebrun and Julie Lecocq propose a three-level classification for FC. The first level represents the foundational stage, where lecturers upload course materials online for students to access outside of class. Classroom activities focus on discussions and exercises, providing more time for collaborative and interactive learning. The second level introduces greater complexity: students are encouraged to conduct preliminary research and readings that form part of the course. In addition to structured discussions and activities, students co-create the course by utilising IT tools or delivering oral presentations. "In the form of a cycle, it would go beyond the deterministic linearity of "before class/during class" to become a spiral made of successive contextualisation (the meaning of knowledge, practices, contexts), decontextualisation (invariants, principles, models, theories), and recontextualisation (applications, situations, transfer)", according to J. Lecocq & M. Lebrun (2016), who describe the third level as a combination of the first two. The hybrid nature of FC – balancing theory and practice, in-person and remote learning, knowledge acquisition and skill development – enables the integration of diverse pedagogical techniques from constructivism, behaviourism, cognitivism, socio-constructivism, and connectivism. As J. Lecocq & M. Lebrun (2016) observe, FC is "a fertile mix of direct transmission (I teach) with a constructivist or socio-constructivist approach to learning (it is up to the learners to learn)", aimed at enhancing students' capacity for autonomous learning, including the knowledge, skills, and interpersonal abilities required to decide what, when, and how to learn.

Therefore, all theoretical information is remotely transferred through a digital platform due to the relationship between presence and distance. This content is provided through an educational platform or institution chosen by the lecturer before class, typically in the form of text files, study materials, or lectures with commentary or videos. The classroom is reserved for assignments that require student engagement and teacher supervision. From the perspective of B.S. Bloom's (1956) taxonomy, the hybrid nature of FC enables the exploration of different levels within the cognitive domain. As shown in Figure 1, the pre-class time is dedicated to lower-level skills, such as "recognising and understanding", which represent the first two levels of the pyramid. Conversely, the four higher levels of the pyramid – "applying, analysing, evaluating, and creating" – can be addressed in the classroom.

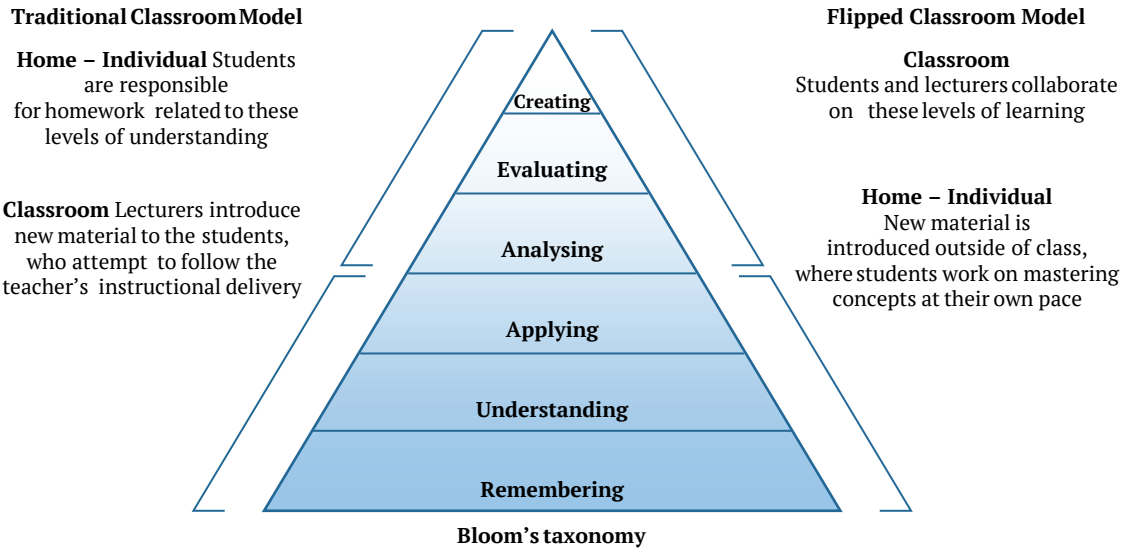


**Figure 1.** Bloom's taxonomy adapted to the flipped classroom by B. Williams

**Source:** developed by the authors based on H. Dufour (2014)

This study supports the conclusions of other researchers regarding the advantages of FC technology over traditional methods (Kuzu, 2007; Danker, 2015). Authors agree that FC promotes student engagement (Kazu *et al.*, 2014; Sohrabi & Iraj, 2016). The relevance of FC technology in the digitalisation era is confirmed by other studies (Kim *et al.*, 2014). Despite the many benefits of FC, its disadvantages must also be considered. First and foremost, such training can only be efficiently organised if students are highly motivated and eager to acquire new knowledge, rather than simply searching for answers to test questions in videos or presentations. It is worth noting that some topics (for example, methods of calculating indefinite integrals of trigonometric or rational functions) do not generate much enthusiasm among students and tend to stagnate at this stage. Students who have not thoroughly engaged with the preliminary material provided will be unable to fully participate in class discussions with the lecturer. The challenge of providing proper technical and methodological training for university lecturers remains significant, as the existing material and technical infrastructure pose difficulties in preparing audio and video lectures. This leads to an increased time commitment for lecturers in preparing lessons, adding to their overall workload. The authors' experience also indicates that this methodology requires well-organised feedback that accounts for the nuances and specificities of the material being taught.

## CONCLUSIONS

It was found that FC is a learning model in which a student-centred approach prevails, and the interaction between the student and lecturer is significantly increased. In this case, the lecturer acts as a mediator of the learning process, rather than an omnipotent guru, and the student is responsible for the learning outcomes achieved through an activity-based constructivist approach. FC technology can be used for both lectures and practical classes on mathematical subjects taught in a foreign language. Modern technologies enable the selection of relevant material and the creation of effective and engaging tasks. Since FC serves as a compromise between traditional and distance learning, students enhance their autonomous learning skills and strengthen their motivation. Despite some drawbacks, this model of teaching promotes student engagement and greatly facilitates learning a foreign language.

The strengths of FC can serve as a motivating factor for many lecturers to adopt FC technology for teaching any subject at the university level, including bilingual education. Innovations in teaching and learning are undoubtedly one of the most important factors determining the success of higher education. The ability of FC to combine several pedagogical approaches and utilise ICT provides a significant advantage when developing innovative teaching methods.

It is recommended to conduct a statistical experiment to determine the impact of FC technology on the delivery of subject content and the development of students' bilingual professional communicative competence. This will further deepen the understanding of FC and its potential benefits in bilingual education at technical universities.

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## CONFLICT OF INTEREST

None.

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# Можливості інтегрування технології «flipped classroom» у білінгвальний курс вищої математики в технічному університеті

**Анотація.** Зміна парадигм вищої освіти, виклики глобалізації зумовлюють необхідність перегляду методів і підходів до викладання дисциплін в українських університетах. Метою даної роботи було узагальнення та аналіз практичного застосування технології перевернутого класу при викладанні курсу вищої математики студентам інженерно-технічних спеціальностей на білінгвальній основі. У роботі використовувались загальні методи наукового дослідження: теоретичні (системний аналіз, порівняння, узагальнення, синтез) та емпіричні (педагогічне спостереження, бесіда, обмін досвідом роботи, вивчення результатів педагогічної діяльності). Описані ступені становлення технології перевернутого класу в історичному ракурсі. Встановлені причини, які зумовлюють застосування даної методики в умовах обмеження соціальних контактів. Проаналізовано переваги даної моделі навчання при вивченні математичних дисциплін на білінгвальній основі. З'ясована істотна роль інформаційно-комунікаційних технологій при використанні моделі перевернутого класу. Детально описано та проаналізовано досвід авторів викладання англомовних математичних курсів майбутнім інженерам із застосуванням технології перевернутого класу в умовах дистанційного навчання. Зазначені можливі недоліки даної моделі навчання. Встановлено, що перевернутий клас – це модель навчання, в якій переважає особистісно-орієнтований підхід, значно збільшується взаємодія між студентом та викладачем, зростає залученість студентів, для них полегшується вивчення предмету іноземною мовою. Результати роботи можуть бути застосовані в процесі викладання фахових дисциплін в технічному університеті, як рідною мовою, так і на білінгвальній основі

**Ключові слова:** білінгвальна освіта; модель білінгвального навчання; предметно-орієнтовані дидактичні моделі; математичні дисципліни; технологія «перевернуте навчання»; інформаційно-комунікаційні технології