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TEACHING HIGHER MATHEMATICS ON A BILINGUAL BASIS: PROBLEMS AND FEATURES

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Changing paradigms of higher education, challenges of globalization necessitate a review of methods and approaches to training future specialists in Ukrainian universities. One of the modern requirements is the training of a specialist who is able to work in a multicultural environment. Bilingual education meets this goal.

The purpose of this work is to highlight the specifics of teaching higher mathematics in English for students of engineering specialties. Some factors affecting the effectiveness of bilingual instruction in engineer education have been analyzed in this paper. These factors play significant roles in promoting the development of bilingual instruction which have been proved in practice. Specific problems that arise for the instructor when teaching in a foreign language are identified, and possible practical ways to overcome them are given. It is shown that these problems do not affect the quality of education provided that the instructor has proper methodological qualifications.

A statistical study was conducted among 1st year students majoring in 141 Power Engineering, Electrical Engineering and Electrical Mechanics. The conducted studies have shown that the factor of learning higher mathematics in a foreign language does not affect the mastery of subject content. This allows expanding the practice of bilingual teaching to professional and general technical disciplines when training future engineers in a technical university.

The results of the study can be the basis for future research: conducting a statistical experiment to identify the influence of bilingual teaching/learning on the formation of bilingual subject competence in mathematics of future engineers; overcoming cognitive costs when learning mathematics in a foreign language.

Keywords: *higher mathematics, foreign language, foreign language education, bilingual teaching/learning model, subject-oriented didactic models, engineering education, academic mobility.*

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ВИКЛАДАННЯ ВИЩОЇ МАТЕМАТИКИ НА БІЛІНГВАЛЬНІЙ ОСНОВІ: ПРОБЛЕМИ ТА ОСОБЛИВОСТІ

Н. В. Сніжко

Зміна парадигм вищої освіти, виклики глобалізації зумовлюють необхідність перегляду методів і підходів до підготовки майбутніх фахівців у вищих навчальних закладах України. Однією із сучасних вимог є підготовка фахівця, здатного працювати в полікультурному середовищі. Цій меті відповідає білінгвальна (двомовна) освіта.

Метою даної роботи є висвітлення специфіки навчання вищої математики англійською мовою для студентів інженерних спеціальностей. У статті проаналізовано деякі фактори, що впливають на ефективність білінгвального навчання майбутніх інженерів. Ці чинники відіграють значну роль у сприянні розвитку двомовного навчання, що доведено практикою. Визначено конкретні проблеми, які виникають у викладача під час навчання іноземною мовою, та наведено можливі практичні шляхи їх подолання. Показано, що ці проблеми не впливають на якість навчання за умови належної методичної кваліфікації викладача.

Проведено статистичне дослідження серед студентів 1 курсу спеціальності 141 "Енергетика, електротехніка та електромеханіка". Проведені дослідження показали, що фактор вивчення вищої математики іноземною мовою не впливає на засвоєння змісту предмета. Це дозволяє поширити практику білінгвального викладання на фахові та загальнотехнічні дисципліни при підготовці майбутніх інженерів у технічному університеті.

Результати дослідження можуть стати основою для подальших розвідок: проведення статистичного експерименту з виявлення впливу білінгвального навчання на формування білінгвальної предметної компетентності з математики майбутніх інженерів; подолання когнітивних затрат при вивченні математики іноземною мовою.

Ключові слова: *вища математика, іноземна мова, іншомовна освіта, модель білінгвального навчання, предметно-орієнтовані дидактичні моделі, інженерна освіта, академічна мобільність.*

Introduction of the issue. Ukraine is integrating into the international scientific and educational area, Ukrainian companies are entering the international market. In these conditions, English is becoming not just a lingua franca, but one of the key factors in the fundamental professional education of an engineer. The requirements of the Bologna process provide for expanding the mobility of scientific and pedagogical workers, students and other personnel for mutual enrichment with European experience; increasing the competitiveness of graduates in the domestic, European and world labor markets. Ukrainian universities are faced with the task of harmonizing Ukrainian and foreign educational programs, ensuring the convertibility of domestic higher education. Training personnel who not only possess modern knowledge, but are also able to apply it in practice in the conditions of globalization, including maintaining documentation and communicating in a foreign language, is becoming increasingly important. Thus, the appeal to bilingual education, in which a foreign language, along with the native language, acts as a tool for learning and self-education, is relevant.

Since the beginning of the 90s bilingual education has been a leading direction of educational policy in many countries of the world. In the process of bilingual learning, a foreign language is a tool for mastering special knowledge. The combination of subject and language components in all links of the educational process is a characteristic feature of bilingual education. Subject-oriented models are gaining relevance. In such models a foreign language is a means of studying a subject (for example, higher mathematics for future engineers).

Current state of the issue. Researchers on the topic agree that over the past twenty to thirty years, English as a Medium of Instruction (EMI) in higher education has become a global phenomenon. In particular, this is stated by A. Vinke, J. Snippe, W. Jochem [22],

B. Fenton-Smith, P. Humphreys, I. Walkinshaw [9], J. Airy et. al. [1]. The spread of English as a learning tool was triggered by the Bologna Process and the emergence of the European Education Area. F. Maiworm, B. Wächter [14; 23], A. Sandstrom, C. Neghina [19] showed that the spread of EMI leads to an increase in the number of programs taught in English at European universities. Studies by C. Dalton-Puffer [7], P. Mehisto, D. Marsh, M. J. Frigols [15], H. Roquet, C. Pérez-Vidal [18] demonstrate that the integration of language and subject components (CLIL, Content and Language Integrated Learning) in teaching professional disciplines has become widespread in the world. A study conducted in 2013-2014 by the British Council presents information on the spread of EMI in Brazil, Colombia, Uganda, Nigeria, Ethiopia, Zambia; some former countries of the socialist bloc (e.g., Bulgaria, Hungary, the Czech Republic, Slovakia), as well as Azerbaijan, Kazakhstan, Ukraine; J. Dearden [8] provides relevant data. B.A. Goodman [10], R. Bolitho, R. West [5], N. Snizhko [20] considered the issue of implementing bilingual education in Ukrainian universities, in particular, in technical ones. R. Klaassen [13], J. Airy [2] highlighted the problems of teaching physics and mathematics subjects in English for non-English-speaking audiences in the training of engineers. Y. Polyezhayev et.al. [17] considered the issue of using digital technologies in teaching in English at Ukrainian universities.

We observe a complex spectrum of attitudes towards bilingual education policies. A. Balula, S. Vasconcelos, A. Moreira [4], W. Baker, J. Hüttner [3] examined different aspects of EMI; R. Klaassen [13] examined teaching and assessment materials, course plans, syllabi, curricula and other institutional documents. Studies by B.A. Goodman [10] and R. Klaassen [13] reveal the problems that students and teachers face in the EMI process: language analysis, student-instructor interaction, and levels of comprehension. The researchers observed and discussed some common problems that are commonly associated with the process of teaching subject content in a foreign language (subject instructor's level of language proficiency, students' English language deficiencies, level of acquisition, alternative methodologies, quality of classroom interaction). However, the authors also concluded that contextual factors are important; many researchers caution against adopting a simplistic, single view. There are unique context-dependent variables that influence the language of instruction in different countries and in different specialties. M.L. Pérez-Cañado [16] cautions against directly transferring the implementation of bilingual teaching methods from one country to another, from one specialty to another.

In Ukraine, modern pedagogical studies of bilingual education appeared on the wave of social renewal, the desire for an open society and integration into the world community. Bilingual education in the domestic system of higher education was studied in the works of such scientists as A. Husak, R. Devletov, A. Kovalchuk, N. Mykytenko, F. Moiseeva, S. Sytnyakivska, and others. Issues related to bilingual education of students of non-linguistic specialties were studied. Some issues of bilingual education in technical universities were considered by S.V. Ivanenko [11], S.M. Sytniakivska, M.H. Khlyvniuk [21]. But it should be noted that at the moment a comprehensive concept of bilingual professional education in Ukraine has not been built. Currently, only certain aspects of the problem of bilingual education in higher education have been defined. We also note that the methodological and technological foundations of bilingual teaching of different professional and fundamental disciplines are almost not developed.

Aim of the research is to highlight the specifics of teaching higher mathematics in English for engineering students; to establish the impact of bilingual teaching/learning on the acquisition of subject content.

Research methods. In recent years, the National University Zaporizhzhia

Polytechnic has been teaching a course on higher mathematics in English for students majoring in 141 Power Engineering, Electrical Engineering and Electrical Mechanics (Electrical Engineering Faculty). This course is not duplicated in the native language. In parallel, students learn other fundamental courses and professional courses also in English. Tests, calculations, exams are also carried out in English. Students of English-speaking groups study according to the same curriculum as students of Ukrainian-speaking groups. The only difference is that students of English-speaking groups have additional hours of English compared to students of Ukrainian-speaking groups.

In 2020-2023, 63 students participated in the study (experimental English-speaking groups – 23 students, control Ukrainian-speaking groups – 40 students). The relatively small number of participants in the study is explained by problems related to the pandemic and military actions in Ukraine. The theoretical basis of the research was the concept of bilingual education. At the practical stage of the research, the main method was the natural pedagogical experiment. Within its framework, purposeful pedagogical observation of students' academic achievements during the educational process with given parameters was carried out; emerging difficulties were recorded. Exchange of experience and study and discussion of the results of pedagogical activity took place at methodological seminars.

Results and discussion. Our experience has shown the most common specific problems that instructors of higher mathematics for future engineers face when teaching in English, as well as possible ways to overcome these problems.

The first problem is the initial level of first-year students' English proficiency. They have to listen to lectures in English, communicate in English in practical classes, and use methodological recommendations and manuals written in English. This is a challenge for them, as they did not have such learning experience in high school. Because of this situation, the instructor may simplify explanations and avoid considering some difficult-to-understand details, although they are very important for understanding the content. This leads to incomplete study of some aspects of the subject. This problem is solved by intensifying the study of English itself in the first year: students of English-speaking groups have additional hours of English compared to students of Ukrainian-speaking groups).

The second problem is obvious: the teaching of a subject in a foreign language takes place at a slower pace. The perception and awareness of information by students is also slower. This takes some time and effort from both the teacher and the students. Therefore, as a rule, in English-speaking groups students have time to process a smaller amount of material than those who learn in their native language within the planned classroom hours for higher mathematics. This can affect the implementation of the curriculum. And here the instructor's experience becomes of great importance: it is necessary to critically approach the selection of material, the sequence of its processing. So, this problem is solved by the instructor's methodical qualification.

Since in Zaporizhzhia Polytechnic the English-language course of higher mathematics is not additional to the Ukrainian-language course, the English-language course is the only course of higher mathematics, the following problem arises. The instructor is faced with the need to duplicate the terminology in his native language. This is necessary in order to have an adequate understanding of the terminology and to use it correctly in a professional context. The instructor must give students the exact equivalent in their native language for each term, and also compile a glossary for each topic. Thus, the problem of adequate mastery of the subject is solved also in the native language.

We see differences in approaches to teaching higher mathematics in Ukraine and abroad. This creates another group of problems. English-language mathematics is more aimed at acquiring practical competencies and skills. It is a well-known

point of view that the main goal of foreign mathematics education is to know-how, and the main goal of domestic mathematics education is to know-why. Ukrainian students enter universities with the knowledge they have acquired at school. They are able to solve non-trivial stereometric problems, systems of equations, operate with trigonometric and logarithmic transformations, and complex numbers. But along with this, first-year Ukrainian students get confused when performing the simplest combinatorial, statistical, and financial calculations, and get lost in graphical information. Moreover, they cannot formalize a task described in terms of a specific life or professional situation. In foreign schools and colleges, the main attention is paid to such skills, this is what is taught in secondary and even primary school. It should also be noted that there are many little things that seem insignificant, but in fact affect the learning process. For example, in English-language mathematics, control, test and examination tasks are presented in a slightly different way than our schoolchildren and students are used to; English-language educational resources use slightly different notations for functions, terms, quantities; standard mathematical formulas have a slightly different appearance. The listed factors do not allow the direct use of only foreign English-language textbooks and manuals. There is a need to create methodological support for the course, which combines the principles of foreign mathematical education and the realities of our school education. We must use English-language methodological manuals (lecture notes, calculation and control works, examples of solving practical tasks, other materials for students' independent work ets.), which contain a list of special terms in English and the native language. Thus, we consider it appropriate to use both original English-language resources and methodological guides created specifically for such courses by our instructors in the educational process to bridge the aforementioned gap between English-language and domestic higher mathematics. For students majoring in 141 Power Engineering, Electrical Engineering and Electrical Mechanics the instructors of the Department of Mathematics have created a set of methodological manuals (workbooks, calculation tasks with instructions, lecture notes), as well as a trilingual mathematical dictionary.

Regardless the above problems, learning higher mathematics in English has obvious advantages:

– students maintain the language skills and improve their English in the process of learning;

– students master special vocabulary, not only mathematical, but also engineering and technical ones. This gives them the opportunity to read articles and textbooks in English more confidently, and also prepares them for further study abroad, joint master's programs with partner universities, internships in English;

– students can prepare more effectively for exams and tests such as IELTS, TOEIC, TOEFL, GRE. These tests are a necessary condition for continuing their studies or working abroad;

– students can freely use English-language periodicals and literature of a special profile, which is much more available in English than in Ukrainian.

In the course of the study, the question arose whether teaching in a foreign language affects the acquisition of subject content. It was hypothesized that teaching/learning mathematics in English has an insignificant effect on mastering the content of the discipline. For this purpose, data on the assessment in higher mathematics of students of the English-speaking and Ukrainian-speaking groups were studied.

The following Table 1 gives the average score in the first and second semesters of study for each group (scale 0-100 points).

Table 1

Assessment in higher mathematics

	2020-2021 academic year		***2021-2022 academic year***		***2022-2023 academic year***	
	1st semester	2nd semester	1st semester	2nd semester	1st semester	2nd semester
English-speaking group	77	73	85	83	60	70
Ukrainian-speaking group	73	73	68	60	71	60

The following Table 2 presents data on two samples: a combined English-speaking group and a combined Ukrainian-speaking group. The null hypothesis about the equality of the means of two unknown distributed populations (independent samples) was tested.

Table 2

Sample data for applying the Z-test

	Sample size, n	***Sample mean, x***	***Sample variance, D***	***Significance level, a***	***Empirical value of the Z-statistic***	***Critical value of the Z-statistic***
Combined English-speaking group (1)	46	71.7826	65.0844	0.05	1.8192	1.96
Combined Ukrainian-speaking group (2)	80	69.3625	28.3810			

We use the Z-test; empirical value of the Z-statistic

$$Z = \frac{|x_1 - x_2|}{\sqrt{\frac{D_1}{n_1} + \frac{D_2}{n_2}}}$$

and critical value of the Z-statistic

$$Z = \Phi^{-1}\left(\frac{1-\alpha}{2}\right),$$

where Φ(t) is a Gaussian function, are calculated. Since the empirical value of the criterion is less than the critical value, there is no reason to reject the hypothesis of equality of the means of the two samples. This means that the differences in the scores of the two groups are due to random factors. The data do not contradict the null hypothesis of equality of the means of the two samples. It can be assumed that teaching higher mathematics in English does not affect the acquisition of the subject content. This result correlates with the conclusions of the study by A. Chin, N. Daysal, S. Imberman [6] on the impact of bilingual programs on learning outcomes. Our study also confirms the results of S. Jianhong et al. [12] on the effectiveness of bilingual instruction for students of engineering and technical specialties.

The research findings were based on a small-scale study with a limited number of participants. However, the general tendency was outlined and the scope of the investigation can be further expanded.

Conclusions and research perspectives. Innovations in teaching and learning are undoubtedly one of the most important factors that determines the success of university education.

Bilingual education of future engineers at technical universities of Ukraine has great prospects in the context of European integration and Ukraine's entry into the international scientific and educational area. The advantages of teaching on a bilingual basis can be a motivating factor not only for students, but also for many instructors to adopt the technology of bilingual teaching of any subjects in a university setting.

The effectiveness of bilingual teaching and, as a consequence, the acquisition of subject content are influenced by a number of factors. The most important of them are the following:

– the initial level of English among first-year students (often low);

– the presence of a parallel course in Ukrainian (usually absent);

– the pace of the lesson (clearly slower, compared to the native language);

– the difference in approaches to teaching mathematics in Ukraine and abroad (manifested in the use of authentic English-language textbooks);

– the availability of appropriate methodological support (insufficient).

The listed factors cause the emergence of specific problems for the instructor:

– the need to simplify the language of explanation, which may affect the correctness of understanding;

– the need to duplicate terminology in Ukrainian;

– working on a smaller amount of material during the scheduled hours, which may affect the implementation of the curriculum;

– the impossibility of using *only* foreign manuals;

– the need to create our own English-language methodological manuals.

The analyzed problems of bilingual teaching/learning mathematics and recommendations for overcoming these problems contribute to a better understanding of the specifics of teaching in a foreign language. And this, in turn, contributes to the involvement of students and greatly facilitates their study of the subject in a foreign language.

Studies conducted among Electrical Engineering students showed that the factor of teaching higher mathematics in English does not affect the mastery of the subject area. Therefore, we believe that bilingual teaching can be used for professional and general technical subjects in the process of training future engineers.

These results can be the basis for future research. We consider it appropriate to conduct a statistical experiment to identify the influence of bilingual teaching/learning on the formation of bilingual subject competence in mathematics of future engineers. The system of communicative qualities of students' mathematical speaking needs more detailed research. This will contribute to further deepening our understanding of the bilingual educational model at a technical university and its potential benefits.

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