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Bilingual education of future natural sciences teachers as today's requirement



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Abstract The article addresses the issue of integrating bilingual education elements into the training of future natural sciences teachers. It has been observed that Ukraine has previous experience in implementing bilingual education in general secondary education institutions. However, a significant limitation in this regard is the inadequate bilingual preparation of future natural sciences teachers. The content of the elective course "Science teachers training in US universities," which is taught in English, serves as a means to establish a "parity model" of bilingual education for future natural sciences teachers and a "displacing model." The course aims to achieve two objectives: first, to familiarize students with the concept of natural sciences teachers training in the United States, including its structure, content features, and pedagogical methods within the context of continuous educational development; second, to foster intercultural interaction skills. Research has indicated that teaching methods incorporating varying levels of assistance during cognitive tasks and differentiated complexity levels are effective in delivering this course. These methods ensure that each student is provided with optimal conditions to satisfy their cognitive needs and develop their communicative skills. The approach involves a gradual transition from collective work to partially independent and fully independent task performance, with an increasing level of complexity. Experimental evidence supports the effectiveness of implementing the course "Science teachers training in US universities."

Keywords: bilingualism, future teachers, natural sciences, elective course, dose of assistance

1. Introduction

The problem statement: It is recognized that current social, economic, and political changes in the world necessitate the active participation of different countries in the global geopolitical multicultural dialogue. The mastery of at least one foreign language has become a crucial factor in intensifying this dialogue. Consequently, the emergence of bilingual education in the world educational practice is a direct response to this need. The research on bilingual training is naturally prompted by the creation and strengthening of interrelations among pedagogical and scientific communities across different countries. The introduction of bilingual education will ensure active communication among educational stakeholders, expand employment opportunities and provide career growth advantages. It is noteworthy that the national policy on training industry specialists, who are recognized by other countries and remain competitive in today's labor market, has undergone significant positive changes, particularly in the realm of foreign language learning, both in general and within professional contexts.

The analysis of recent studies and publications: The development of bilingual education in Ukraine, driven by the general trend towards integration into the European space and the aspiration for intercultural dialogue and communication, can be traced back to its historical roots. In the 1960s and 1970s, bilingual learning technologies were actively introduced in general secondary schools that focused on advanced foreign language education. Drawing upon our own experience, we recall that during that time, for instance, Ternopil School No. 3, which specialized in foreign language learning, taught the subject "Geography" in a foreign language (English) at the 6th-grade level. Subjects such as "English Literature," "American Literature," "Technical Translation," and "United States Navy" were incorporated into the high school curriculum as additions to the "English" subject. Every Tuesday, political information (reports on recent domestic and international events) was delivered in English, encompassing all high school students. Additionally, there was an English day once a week, during which all programs on the school radio were broadcasted in English. This experience has endured and continues to be actively employed. However, both then and now, the challenge remains in training teachers who possess, for example, a natural sciences education and can effectively teach schoolchildren in English. All these factors underscore the need for introducing bilingual education into the professional training of future natural sciences teachers.



The state and prospects of future natural sciences teachers' training were the subjects of our study (Stepanyuk and Olendr 2019). Regarding bilingual education, the analysis of literature sources revealed that the theoretical foundations of bilingualism in Ukraine are expounded upon in the works of several scholars (Bodnarchuk 2013; Horoshkina 2012; Ihnatenko 2014; Kotlovskiy et al 2020; Sytniakivska and Khlyvniuk 2015; Shirin 2003). Their research substantiates that bilingual education is a purposeful process of engaging with world culture through both native and foreign languages, wherein the foreign language serves as a means of understanding the world, acquiring specialized knowledge, and learning about the cultural, historical, and social experiences of different countries and peoples. Although the forms of utilizing two languages, as well as the types of didactic materials and their language, are not regulated, it is imperative that their level corresponds to the average language competence of the reference group.

The studies conducted by Sytniakivska and Seiko (2018) compared the students' attitudes toward bilingual education in Ukraine and Poland. Bartosh (2021) conducted a study that generalized the ideas from the American experience, focusing on bilingual education as a means to ensure effective intercultural interaction in a multinational state.

In foreign pedagogy, various currents of bilingual direction have been identified. Bilingual education was studied by representatives of the American scientific school to facilitate the integration of national minorities into the dominant culture (Fishman 1976). Notably, researchers such as D. Baker, D. Basaraba, and P. Polanco examined the effects of bilingual education on academic performance, compared its impact on writing, science, and mathematics, and explored the cognitive benefits of bilingualism (Baker et al 2016).

European practice is familiar with bicultural contact classes, which promote an intensive dialogue of ideas, educational and lifestyle approaches, traditions, and cultures among children from different linguistic and ethnic backgrounds. Contact classes emphasize the parity of the two languages of instruction and the equality of represented cultures, giving bilingual education and multicultural education a special moral significance (Hamers and Blanc 2000).

Our work (Olendr et al 2021) partially addressed the problem of introducing elements of bilingual education into the professional training of future natural sciences teachers. Such education offers the advantage of progressing toward multicultural education. However, it is hindered by the imperfections in the system of bilingual teacher training and the lack of suitable textbooks. Bilingual education encompasses various models and programs, all based on the principle of using two languages as a means of instruction. These models include dubbing or *accompanying, supplementary, parity, and displacing models*. Each model requires further research regarding its content.

This article aims to develop the content of the elective course "Science teachers training in US universities," taught in English as a means of bilingual education for future natural sciences teachers, and to experimentally substantiate its effectiveness.

2. Methodology

To achieve the aforementioned goal, several methods have been employed, including theoretical-comparative analysis to explore different perspectives on the problem and identify areas of study, modeling to develop a model of the elective course "Science teachers training in US universities," constructing to develop the course component and criteria for research, and systematization and generalization to formulate conclusions and recommendations for improving the educational process and raising the quality of educational services at higher education institutions. Additionally, empirical methods such as generalization of pedagogical experience, scientific observation, interviews, content analysis, and questionnaires were utilized to assess the implementation of the problem in practice and develop the content of the experimental teaching methodology. The effectiveness of the proposed methodology was verified through a pedagogical experiment, which involved expert evaluation of the developed experimental materials.

The experimental research was conducted at Ternopil V. Hnatiuk National Pedagogical University, focusing on the professional training of future natural sciences teachers. The effectiveness of the proposed methodology was evaluated during a two-year period spanning the 2019-2020 and 2020-2021 academic years. The research involved 21 lecturers from higher education institutions and 105 students at the second (master's) level of the educational and professional program in Secondary Education (Natural sciences). Eighty individuals participated in the summative stage of the experimental research, while 25 individuals were involved in the forming experiment.

The methodology of the experimental research encompassed several stages: the preparatory stage, which involved studying the needs of the educational interaction subjects and identifying the requirements for improving the quality of educational services; the organizational and methodological stage, where priorities were determined among students regarding educational and organizational activities related to the proposed course; the procedural stage, which involved the study of the proposed course; and the reflexive-analytical stage, where the results of the experimental training were analyzed based on objective and subjective indicators.

3. Results and discussion

The development of the issue regarding the introduction of elements of bilingual education in the training of future natural sciences teachers was based on the assumption that such training is more effective than classical approaches. The aim

is to facilitate the development of students' general competencies, enabling them to compete in the Ukrainian labor market and globally. Additionally, it was considered essential to incorporate positive experiences from professional teacher training abroad, particularly in the USA, to effectively address the continuous improvement of professional training in higher pedagogical educational institutions. The USA stands out as a country where multicultural education is a public policy regulated by the Bilingual Education Act. It also recognizes the importance of interpreting education as a continuous learning process, emphasizing the degree of competence aging and the half-life of knowledge. Moreover, the USA demonstrates a high level of development in natural science education, which enhances the professional competence of teachers (Shirin 2003).

To introduce bilingual education in the professional training of teachers, a program for the course "Science teachers training in US universities" was developed in 2020. This course is part of the block of elective disciplines in the methodological direction and has been incorporated into the curriculum for second-level (master's) students specializing in Secondary Education (Natural Sciences) and Secondary Education (Biology and Human Health) at the Faculty of Chemistry and Biology of Ternopil Volodymyr Hnatiuk National Pedagogical University. The course serves a dual purpose: to provide students with knowledge of the concept of training natural sciences teachers in the United States, encompassing its structure, content features, and forms and methods of teaching natural sciences teachers in the context of continuing pedagogical education; and to develop intercultural interaction skills. Notably, the course is taught in English, tailored to the students' foreign language competence levels.

Since students at the second (master's) level of higher education have varying levels of knowledge and skills in the foreign language, the teacher must employ different methods and approaches to foster foreign language competence during language instruction. Drawing upon the findings of previous research (Malykhin and Bondarevska 2018; Zadorozhna et al 2019; Kotlovskyi et al 2020; Morska 2018; Nikolaeva et al 2019; Zadorozhna et al 2019) and classroom experience, it has been concluded that teaching methods involving different levels of assistance during cognitive tasks are effective. These methods provide optimal conditions for satisfying each student's cognitive needs and interests while mastering educational material and developing communicative skills. Task planning takes into account students' proficiency levels, allowing for the creation of tasks of varying complexity and corresponding discussion groups. The lecturer provides tasks and adjusts the level of assistance according to each student's needs. As the training progresses, there is a gradual transition from collective work to partially independent and fully independent tasks, increasing in complexity.

Lectures encompass the study of general issues related to the organization and content of future natural sciences teachers' training in the United States, as well as the forms and methods of professional training and quality monitoring of natural sciences education in US universities. Thus, the following topics are covered: "Formation of the future natural sciences teacher's professionalism and their professional and methodological competence," "Normative sources of constructing the content of natural sciences teachers' training in the US," "Content, forms, and methods of natural sciences teachers' professional training for the beginning of pedagogical activities," "Organization of natural sciences teachers' professional training during pedagogical activities," "Methods of teachers' professional training in the USA," "Peculiarities of the organization of future natural sciences teachers' professional training in the USA and Ukraine," "Concept of monitoring: The essence and criteria of monitoring of education in US universities," "Structure and standards of natural sciences education in US universities," "Monitoring studies of students' outcomes quality in US universities," and "Process and result as components of monitoring the quality of natural sciences education".

Practical classes aim to deepen the understanding of the main topics covered in the lectures by studying components that ensure the high professionalism of natural sciences teachers in the United States. The main normative sources that determine the essence of professional training and pedagogical activities of natural sciences teachers in the United States, as well as the features of curricula for natural sciences teachers' training in the United States and methods of natural sciences teachers' professional training in the USA, are explored.

The content of the course is divided into two thematic modules: "Training of a natural sciences teacher in the USA" and "Monitoring the quality of natural sciences education in the USA." The structured nature of the course allows for easy expansion of its scope and variation in the topics covered. During independent work, students engage with literary, scientific sources on the problems that are partially explained during lectures or discussed in practical classes.

The educational materials intended for students' self-study are suitable for independent study according to the level of difficulty. These materials expand, supplement, and specify the knowledge of the fundamentals studied in the basic course. They include practical materials that illustrate the application of general principles, such as components of natural sciences teachers' professional training in the United States, main stages of pedagogical practice at school, types of professional training methods implemented during the study of natural sciences and their characteristics, main differences between the Ukrainian and American systems of pedagogical education, comparative analysis of the content of American and Ukrainian training programs for future natural sciences teachers, and characteristics of the requirements for professions in the field of knowledge "Natural Sciences". The total number of hours assigned for students' independent work is 52 hours.

The formation of independence in the acquisition and deepening of knowledge, which will increase the competitiveness of future specialists in the labor market, is the purpose of the student's independent work. It has been observed that independent work becomes effective in teaching English for professional purposes during the 5th and 6th years of study, as it

allows for the optimization of the educational process while students are engaged in different projects, specialized disciplines, and the preparation of their master's thesis. To enhance the organization of students' independent work at higher education institutions, information technologies and e-learning environments are successfully employed. It should be noted that such conditions lead to improved learning outcomes and the acquisition of additional information processing skills, thereby increasing motivation.

The formation of skills to plan and organize their learning strategy and the development of autonomous learning skills are important outcomes of this training. Consequently, the role of the lecturer undergoes a transformation, shifting from a traditional mentor to an organizer and moderator of the educational process. Acting as a partner and assistant, the lecturer supports, guides, and monitors the cognitive activity of future specialists. Proper organization of the educational process is one of the main tasks for the lecturer.

Students' research work focuses on mastering the skills of independent information processing, primarily through the analysis and comparison of elements related to the training of natural sciences teachers in Ukraine, the United States, and Europe. Additionally, students compile glossaries for various topics and translate abstracted texts. The process of natural sciences teacher's certification is also studied. A notable example of research work is scholarly studies examining lesson plan development and preparation for conducting lessons. In order to integrate educational and scientific research activities for students, a web page called "Scientific Progress" has been created on the official website of Ternopil Volodymyr Hnatiuk National Pedagogical University. This page houses a collection of scientific papers under the series "Biology" titled "The Scientific Issues of Ternopil Volodymyr Hnatiuk National Pedagogical University," as well as materials from annual international scientific-practical conferences such as "Physics, Chemistry, Biology, and Natural Sciences Teachers Training in the Context of the Requirements of the New Ukrainian School" and "Ternopil Bioscience." These platforms provide undergraduates with the opportunity to showcase the results of their research.

The organizational and methodological support of the educational process is based on the development of an educational and methodological complex for the course, which includes the program of the course, syllabus, textbooks and manuals, methodological materials and tasks for lectures and practical classes, individual tasks for students' independent work, and current and final tests to assess the students' level of knowledge acquisition.

To determine the criteria for the effectiveness of the course, the essence of the general competencies that future teachers should possess according to the Professional Standard for Teachers (2020) and a student survey were analyzed. The obtained results allow us to conclude that the course "Science Teachers Training in US Universities" has the greatest impact on the formation of general competencies such as mastery of communication skills (according to 92% of the respondents), ability to search, process, and analyze information from various sources (96%), and ability to apply best practices in professional activities (84%). Therefore, two criteria have been selected: the level of development of mental activity techniques (IQ) and the development of speech activities.

The first criterion is seen as an integrated indicator of the formation of the ability to analyze, compare, and draw conclusions from known theoretical information and practical activities. It was determined based on the analysis of students' opinions regarding the diversity and effectiveness of teaching methods employed by lecturers at Ukrainian higher education institutions. Students arrived at their conclusions by comparing the theoretical knowledge gained during the course with their personal experiences and the real practices of future natural sciences teachers' training.

The second criterion was established based on the reflection of students' own achievements in mastering the four main types of speech activity: *reading and reading comprehension*, listening and listening comprehension, speaking, and writing. Various sources, such as adapted and non-adapted popular and scientific sources, lecture materials, manuals, textbooks, scientific articles, tests, media, English texts from web-based resources, including software for the use of English-language sites, annotation and abstracting of texts, were utilized for reading and reading comprehension. *Listening and listening comprehension* involved understanding the teacher's speech during lectures, interpersonal communication during practical classes, audio-Internet conferences, round tables, seminars, authentic audio recordings of scientific films, and feature films of socio-pedagogical orientation. *Speaking* activities encompassed both monologue and dialogue speech during classes, communication during practice, and delivering speeches at conferences with the participation of foreign scientists. *Writing* tasks included writing notes during lectures, performing social and pedagogical tasks, writing abstracts for scientific articles, composing resumes for further employment, preparing scientific reports for participation in grants, and writing theses and reports for international student conferences.

To evaluate the quality of the proposed course, an integrated criterion of "didactic quality" was employed, which was determined through expert assessments. A group of experts consisting of scientists and lecturers from pedagogical higher education institutions across Ukraine was formed to conduct the research. The composition of the expert group intentionally varied to consider a wide range of opinions regarding the alignment of the proposed content with the needs, real conditions of teaching practice, and the current state of pedagogical science. The experts exhibited high levels of competence, interest in the examination results, a businesslike character, objectivity, and impartiality.

The expert group included lecturers and scientists from Ternopil Volodymyr Hnatiuk National Pedagogical University and Sumy State Pedagogical University named after A.S. Makarenko, as well as students at the master's level of higher

education. Among the 21 respondents, there were 6 Doctors in Pedagogical Sciences, 5 PhD and Associate Professors, and 10 students.

Out of the total number of experts, a subgroup of 5 highly competent specialists in the field of the studied problem was selected. This subgroup comprised foreign language lecturers and methods of teaching natural sciences lecturers with more than 10 years of degree and teaching experience.

This group of experts agreed upon the indicators used to assess the content of the courses. As a result of collective discussion, following the condition that $\sum_{i=1}^6 = 100\%$, the "weight" (K) of each of the six selected indicators was determined. The results of this determination are presented in Table 1.

Table 1 The weight of indicators of the content of courses' didactic quality.

#	Indicators	Weight
1.	Significance for soft skills formation, which is listed in the educational and professional program	25
2.	Significance for hard skills formation, which is listed in the educational and professional program	25
3.	Significance for the organization of interactive pedagogical cooperation of the educational process participants	10
4.	Accessibility for perception	10
5.	The expediency of use during future teachers' professional training	20
6.	Correspondence to the life experience of scientists, lecturers, and students	10

The examination was carried out in May 2019, evaluating four components of the course "Science teachers training in US universities": I - lectures, II - practical classes, III - tasks for independent work, IV - control and reflexive tasks. The content of each component was assessed based on the integrated indicator of "didactic quality," which measured the level of alignment with the identified indicators.

The invited experts were briefed on the objective of the experiment and the rules of its implementation. They received information regarding general approaches to addressing the problem. Subsequently, each expert individually completed a questionnaire assessing a set of factors. The questionnaires were then studied and analyzed.

The results of the expert assessment convincingly demonstrated the possibility and relevance of including the course "Science teachers training in US universities" in the curriculum for second-level (master's) students pursuing higher education in the educational and professional program of Secondary Education (Natural Sciences). According to the experts, the course content is overall accessible and important for enhancing the quality of future teachers' professional training.

To evaluate the quality of the proposed course, the students were asked to respond to questionnaires after studying it. The first question required them to indicate the forms, methods, techniques, and technologies used by teachers during lectures to facilitate the educational process. The students were provided with a list of methods and techniques, and they had to categorize each one as "often," "rarely," or "never." The analysis of the students' answers revealed that the following methods were frequently employed during the training of future natural sciences teachers: lecture-discussion (64% of respondents), discussion in subgroups (68%), working in pairs during the lecture (60%), and free discussion (32%). Additionally, 80% of respondents stated that lectures were often conducted in the form of a lecturer's monologue, which differs from the typical approach in US universities.

The following methods were rarely used during lectures: voting (84%), press conference (64%), brainstorming (20%), special guest invitation (92%), training groups (40%), debates (48%), problem solving (56%), lecture-excursions (60%), and work in self-assessment groups (80%). The respondents mentioned several methods that are commonly used in US higher education institutions but were never encountered by them, including binary lectures (96%), "feedback cards" (80%), aquarium (88%), Abercrombie groups (82%), outdoor classes (56%), role-playing games (64%), syndicates (60%), flipped lectures (96%), lectures with pre-planned mistakes (76%), and debates (40%).

In response to the question "What techniques, methods, and technologies are used during seminars?", the respondents frequently noted the use of presentations and discussions (92%), working in pairs (64%), project work (56%), and brainstorming (40%). Among the methods that were rarely used during seminars were self-assessment groups (40%), "flow of ideas" (64%), round table discussions (52%), essay writing (64%), situation modeling (56%), training groups (60%), "microteaching" (52%), and case studies (36%). The following technologies were never employed during seminars according to the respondents: Abercrombie groups (80%), video recordings of students' micro-teaching and subsequent discussions (88%), press conference (52%), role-playing games (72%), interdisciplinary seminars (56%), special seminars (52%), syndicates (64%), and "decision tree" (72%).

During laboratory and practical classes, teaching was often organized using various methods, such as working with equipment (96%), conducting experiments (100%), frontal surveys (96%), individual surveys (100%), testing (88%), performing experiments (64%), conducting research (68%), problem solving (76%), observation of objects (72%), doing exercises (84%), and demonstrations (68% of respondents). Methods that were widely used in natural sciences teachers' training in the United States but rarely among Ukrainian students included project work (64%), heuristic conversations (48%), and creating visual teaching aids (40%). According to the respondents, none of the listed methods were classified as "never used".

An analysis of the answers to the question "What methods of independent work do you use during studying?" revealed that independent work is often organized using methods and techniques such as report preparation (64%), working with various literature (68%), problem solving, calculations, exercises, and individual tasks (76%), answering control or test questions (84%), performing individual research tasks (64%), and independent project work (40%). The following technologies were rarely used in organizing students' independent work: writing abstracts (52%), essay writing (64%), and working with scientific articles (52%).

The qualitative analysis of students' answers indicated a sufficient level of formation of their mental activity techniques, which they effectively utilize in non-standard conditions of a changing educational environment and draw appropriate conclusions.

The quality of educational services provided was assessed based on the second criterion by analyzing the results of students' reflections on the improvement of their proficiency in the four types of speech activity as a result of mastering the course content (Table 2).

Table 2 Results of students' reflection on increasing the level of their speech activity.

#	Type of speech activity	Increased considerably	Increased partially	No changes
1.	Reading and reading comprehension	28 %	60%	12%
2.	Listening and listening comprehension	32%	60%	8%
3.	Speaking	80%	16%	4%
4.	Writing	4%	20%	72%

The results of students' reflection on increasing of their personal achievements showed that their foreign language competence improved. The best results are concerned with such type of speech activity as speaking. Thus, in the students' opinion, 80% of them began to speak much better in English, 16% - partially improved this type of speech activity and only 4% did not show any changes in speaking English. All of them praise the results of mastering the course.

4. Conclusions

The inevitable spread of bilingual education in Ukraine brings forth numerous challenges related to its organization, goal-setting, and evaluation of outcomes. The conducted research aims to establish a solid foundation for training a new generation of teachers who possess high levels of intellectual development and emotional intelligence, while also fostering the creation and development of contemporary models for personal growth among teachers.

The inclusion of the elective course "Science teachers training in US universities" in the curriculum for future natural sciences teachers greatly contributes to engaging students in global culture through the medium of a foreign language. This approach facilitates the exploration of the world, the acquisition of specialized knowledge, and the study of cultural, historical, and social experiences of diverse countries and peoples. Moreover, it expands the prospects for future specialists to adapt to various social, informational, and scientific realities of the modern era, while enhancing the quality of intercultural communication, an increasingly vital skill in a globalized world. Moving forward, there are promising prospects for further content development in other courses aimed at the professional training of future natural sciences teachers..

Ethical considerations

Our study correctly followed the ethical policies for a study that includes human subjects and all the survey participants were aware of the study. All the respondents who were involved confirmed their consent (*Conclusion of the Commission on the Issues of the Ethics of Scientific Research and Experimental Developments of Ternopil Volodymyr Hnatiuk National Pedagogical University. № 86/40-03 of 03.02.2023*).

Conflict of Interest

The authors declare that they have no conflict of interest.

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