

Snizhko Natalia Cand. of Sci. (Physics and Mathematics), Assoc. Prof., Dept. of Mathematics
National University «Zaporizhzhia Polytechnic», Ukraine

PEDAGOGICAL MODELING AS A FRAMEWORK FOR BILINGUAL MATHEMATICS INSTRUCTION AT A TECHNICAL UNIVERSITY

In this study, we consider pedagogical modeling as the methodological foundation for constructing a model of bilingual mathematics instruction in a technical university within the context of globalization and the internationalization of higher education. Contemporary transformations in the global educational space, together with the increasing demand for competitive, mobile, and multicultural professionals, require the modernization of higher education in accordance with a humanistic and competence-based paradigm. One of the most significant trends in this process is the growing role of English as a universal language of academic, scientific, and professional communication. In this regard, bilingual education, based on the integration of Ukrainian and English, becomes an effective means of aligning national higher education with European and global standards. We interpret bilingual instruction not simply as the parallel use of two languages, but as an integrative didactic approach in which a foreign language functions as a tool for mastering disciplinary knowledge, professional terminology, and academic discourse. Since mathematics is a fundamental discipline in engineering education and provides the conceptual and methodological basis for specialized technical subjects, the development of a scientifically grounded model of bilingual mathematics instruction in a technical university is both relevant and strategically important.

We rely on pedagogical modeling as a key method of scientific inquiry and educational design [3]. Modeling integrates empirical and theoretical levels of knowledge and enables the construction of pedagogical systems grounded in experimental data, logical structuring, and scientific abstraction. A model does not merely reproduce reality; rather, it serves as an instrument of cognition that identifies essential characteristics of an object and makes it possible to forecast educational outcomes. Through modeling, complex educational phenomena can be represented in a structured and analyzable form, which facilitates purposeful planning and management of the learning process. In pedagogy, modeling performs both research and practical functions: it structures content, optimizes methods and

forms of instruction, enhances coordination between objectives and outcomes, and supports the integration of academic study with professional preparation [1]. At the same time, we acknowledge that no pedagogical model can fully replicate the multifaceted and dynamic nature of real educational processes. Consequently, the central issue is not absolute completeness, but validity, namely, the degree to which a model adequately reflects the essential properties and relationships inherent in the educational phenomenon it represents.

In constructing the model of bilingual mathematics instruction, we take into account different orientations of educational systems. An internally oriented system primarily serves the needs of the national labor market and tends to function as a relatively closed structure focused on preparing specialists for domestic professional contexts. In contrast, an externally oriented system, characteristic of democratic and globally integrated societies, promotes professional mobility, personal autonomy, intercultural competence, and readiness for participation in international academic and professional environments. We argue that bilingual mathematics instruction corresponds to an open educational model, since it expands students' opportunities beyond national boundaries, fosters adaptability to changing conditions, and supports integration into the global scientific and professional community. Such an approach not only ensures the transmission of established mathematical knowledge but also encourages students to engage critically with information, apply it creatively, and participate in the production of new knowledge.

From the standpoint of pedagogical typology, we view the bilingual mathematics instruction model as structural-functional [2]. It reflects both the structure of the bilingual learning process and the interrelations among its components, while being oriented toward a clearly defined objective (the formation of bilingual subject competence in mathematics). This competence encompasses not only mastery of mathematical concepts, methods, and problem-solving strategies, but also the ability to understand, interpret, and produce mathematical discourse in both the native and English languages. At the same time, the model incorporates features of semiotic and imitation models. The semiotic dimension is обусловлений symbolic nature of mathematics, which relies on signs, formulas, graphs, and specialized terminology. In a bilingual context, students must operate with these semiotic systems in two languages, establishing correspondences between conceptual structures and linguistic forms. The imitation dimension is determined by the applied role of mathematics in engineering education: instructional tasks should simulate professional situations in which mathematical tools are used to solve practical engineering problems. Such contextualization strengthens

motivation and enhances the transfer of knowledge to future professional activity.

In developing the didactic model, we proceed from the necessity of defining precise learning objectives that integrate subject and language components. These objectives must reflect the gradual formation of bilingual subject competence and correspond to the cognitive and professional development of students. Content selection should be based on principles of continuity and progression, ensuring that each new topic builds logically on previously acquired knowledge while simultaneously introducing new linguistic and conceptual elements. We emphasize the importance of balancing mathematical rigor with linguistic accessibility, so that language serves as a means of deepening understanding rather than as an additional obstacle. The planning of tasks and assessment procedures must take into account both the mastery of mathematical content and the development of communicative skills in the foreign language.

We distinguish three interrelated components of the didactic structure: organizational, content, and procedural. The organizational component reflects successive stages of learning activity. At the initial stage, students engage in receptive activity, perceiving and comprehending new mathematical material presented bilingually. This is followed by reproductive activity, during which students reproduce definitions, theorems, and solution algorithms orally and in writing in both languages. At the productive stage, learners apply acquired knowledge to standard problems, demonstrating an ability to operate with mathematical concepts bilingually. Finally, at the creative stage, students solve non-standard problems, independently formulate solutions, and justify them using appropriate mathematical and linguistic means. Such staged organization ensures a gradual transition from comprehension to independent and creative application.

The content component involves dividing mathematical material into logically complete and pedagogically accessible elements. Each element must be manageable within a defined time frame and interconnected with previous and subsequent material. The cumulative principle is essential: new content should not replace previous knowledge but integrate and expand it, thereby preventing fragmentation and promoting systemic understanding. In a bilingual context, the content component also includes the careful selection of terminology, definitions, and explanatory texts in both languages, as well as the identification of linguistic structures necessary for expressing mathematical reasoning.

The procedural component encompasses teaching methods, instructional tools, and forms of assessment. Methods may include explanatory-illustrative approaches, problem-based learning, interactive discussions, and project-based tasks that require

bilingual communication. Instructional tools can range from textbooks and digital resources to visual representations and symbolic models that facilitate comprehension. Assessment should be continuous and multifaceted, evaluating not only the correctness of mathematical solutions but also the clarity and accuracy of their presentation in both languages. Such an approach ensures comprehensive monitoring of learning outcomes and provides feedback for further improvement.

Recognizing the inherent limitations of any formalized system, we emphasize that the validity of the proposed model depends on its systemic character. The model must demonstrate integrity, hierarchy, emergence, functionality, and synergy. Integrity implies that modification of any component influences the entire structure. Hierarchy indicates that the model functions as a higher-order system relative to its individual elements, each of which may itself possess internal structure. Emergence means that the effectiveness of bilingual mathematics instruction arises from the coordinated interaction of components rather than from their simple aggregation. Functionality requires that each component perform a clearly defined role in achieving the overall objective. Synergy ensures that disruption of one element affects the stability and productivity of the whole system. Adherence to these systemic principles guarantees coherence, consistency, and pedagogical effectiveness.

On this basis, we define the structural components of the bilingual mathematics instruction model in a technical university as follows: a target component, which formulates strategic and operational goals; a conceptual component, which outlines theoretical approaches and guiding principles; a content component, which establishes criteria for selecting and integrating subject and language material with gradual complication; a technological-operational component, which describes stages, forms, methods, and instructional tools; and an evaluative-resultative component, which determines criteria and levels for assessing the formation of bilingual subject competence in mathematics. The coordinated interaction of these components forms a coherent structural-functional framework that integrates linguistic and mathematical dimensions of learning, supports professional orientation, and provides a solid theoretical basis for practical implementation in technical higher education institutions.

References:

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