International Journal of Evaluation and Research in Education (IJERE)
Vol. 15, No. 6, December 2026, pp. 5671~5679
ISSN: 2252-8822, DOI: 10.11591/ijere.v15i6.39803

Models of formation of information competence of future biology teachers in the context of multilingual education

Bektemirova Gulnaz[1], Izbassarova Rimma[2], Nagima Umirzakova[3], Gulbarshyn Abeuova[4]
[1]Department of Biology, Kazakh National Women's Teacher Training University, Almaty, Kazakhstan
[2]Department of Biology, Kazakh National Pedagogical University named after Abai, Almaty, Kazakhstan
[3]Department of Natural Science and Physical Education Pedagogy, Almaty Humanitarian Economic University, Almaty, Kazakhstan
[4]Department of Anatomy with Courses, Kazakh-Russian Medical University, Almaty, Kazakhstan

Article Info

Article history:

Received Apr 5, 2026
Revised Aug 6, 2026
Accepted Sep 21, 2026

Keywords:

Educational paradigm
Knowledge-based approach
Professional education
Teaching foreign languages
Teaching strategies

ABSTRACT

The evolving demands of contemporary society require the preparation of highly skilled, competent, and competitive specialists. Among the primary objectives of the current educational paradigm is the development of innovative educational technologies that foster the formation of core professional competencies in graduates throughout the university learning process. In this context, future pedagogical professionals in the natural sciences must not only be equipped to teach science subjects (such as biology, chemistry, physics, and mathematics) in English but also possess the ability to establish professional relationships in cross-cultural communication environments. The key findings highlight the urgent need for reform in teacher education programs, beginning with instruction in students' native languages. This approach promotes deeper comprehension and more active engagement in the learning process. The discussion further addresses the adaptation of pedagogical practices to accommodate linguistic diversity, as well as the critical challenges related to teacher training and resource availability.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Bektemirova Gulnaz
Department of Biology, Kazakh National Women's Teacher Training University
Bogenbai Batyr Street 142, Almaty, Kazakhstan
Email: bektemirova88@mail.ru

1. INTRODUCTION

In the context of globalization and digital transformation, teacher education systems are increasingly expected to prepare future educators for multilingual, technology-enhanced, and culturally diverse classrooms. This challenge is especially important in science education, where effective teaching requires not only subject knowledge but also the ability to communicate complex scientific concepts through multilingual and digitally mediated instruction. Consequently, the development of foreign language professional communicative competence (FLPCC) has become an essential component of professional preparation for future biology teachers.

The importance of multilingual education was formally recognized by the European Commission in 1995, which advocated greater integration of foreign languages into academic instruction. Since then, numerous studies have demonstrated that multilingual learning enhances cognitive flexibility, metalinguistic awareness, critical thinking, intercultural communication, and professional adaptability. More than 150 empirical studies conducted over recent decades confirm that students educated in multilingual environments often outperform their monolingual peers in problem-solving and communicative flexibility [1]–[6]. Despite the growing demand for multilingual science instruction within Kazakhstan's trilingual educational reform,

many pre-service teacher education programs still treat language development, subject pedagogy, and digital competence as separate domains rather than as interconnected professional capacities. This fragmentation creates significant professional challenges for future biology teachers, who are expected to teach complex scientific concepts, use English-medium scientific terminology, and integrate digital technologies without receiving coherent interdisciplinary preparation [7]–[12].

This fragmentation has direct educational consequences. In multilingual biology classrooms, insufficient integration of language, pedagogy, and technology can reduce students' comprehension of scientific concepts, weaken classroom interaction, limit participation in inquiry-based learning, and hinder the development of scientific literacy. Teachers who lack integrated preparation frequently experience difficulties in managing multilingual communication, adapting instructional materials, and using information and communication technologies (ICT) to support conceptual understanding. Consequently, students may struggle with scientific terminology, the interpretation of visual-digital biological representations, and meaningful participation in collaborative learning activities.

Previous research has established the importance of multilingual education for participation, inclusion, and academic development [13], [14]. At the same time, science education scholars emphasize that inquiry-based learning and scientifically oriented communication are essential for improving students' reasoning skills and science, technology, engineering, and mathematics (STEM) readiness [15]. However, despite these advances, research on multilingual education, communicative competence, and ICT-oriented teacher preparation has largely evolved independently.

The integration of ICT into biology education has demonstrated considerable potential for enhancing both teaching and learning processes globally. Numerous studies highlight the transformative role of ICT in facilitating the delivery of complex biological content, improving the visualization of abstract processes, and fostering deeper student engagement through simulations, virtual laboratories, and multimedia learning environments [16]–[21]. Nevertheless, ICT-related studies frequently focus on technical readiness while giving insufficient attention to the linguistic and epistemic demands of multilingual biology instruction.

In parallel, communicative competence has emerged as a critical component of effective content and language instruction. As conceptualized by Kaveh and Estrella-Bridges [22], communicative competence includes not only grammatical accuracy but also sociolinguistic and pragmatic knowledge concerning appropriate communication in specific contexts. Research demonstrates that communicative competence develops most effectively through learner-centered, professionally oriented interaction [23], [24]. Moreover, scholars emphasize that teachers' professional identity and instructional effectiveness are closely linked to communicative and intercultural capacities [25]. In science education specifically, embedding subject-specific language into classroom instruction significantly enhances both conceptual understanding and professional language development [26]–[30].

Although prior studies have examined multilingual education, content and language integrated learning (CLIL)-based instruction, communicative competence, and ICT integration separately, these research strands rarely explain how linguistic, technological, and biology-specific pedagogical competencies should be cultivated simultaneously within pre-service teacher education. Therefore, the central research gap lies in the absence of an integrated pedagogical framework specifically designed for the intersection of multilingual education, biology teaching, and digital competence development in teacher preparation programs. This gap is particularly important in the Kazakhstani context, where trilingual education reforms place increasing demands on future STEM educators while existing curricula remain insufficiently coordinated.

The proposed model is theoretically grounded in the principles of CLIL and the technological pedagogical content knowledge (TPACK) framework. CLIL provides the foundation for integrating language and subject learning, which is essential in multilingual biology instruction, where subject understanding depends on the precise use of scientific terminology [1]–[6]. TPACK complements this perspective by explaining how technological knowledge must interact with pedagogical and disciplinary expertise to support effective teaching and digitally mediated learning environments [7]–[12]. Taken together, these frameworks justify the need for an integrated competency model in which biology teachers are prepared not only to know biology but also to teach it through multilingual communication and digital mediation.

The scientific novelty of this study lies in the development of an integrated model for the formation of information competence among future biology teachers in the context of multilingual education. Unlike existing approaches that address language proficiency, digital competence, and subject-specific pedagogical knowledge separately, the proposed framework combines linguistic, technological, and biology-specific pedagogical competencies into a unified system of professional teacher preparation. A further innovative aspect of the study is its focus on the preparation of biology teachers within Kazakhstan's trilingual educational environment, taking into account the specific requirements of scientific terminology, digital learning technologies, and intercultural communication. The study also expands the theoretical understanding

of translanguaging by conceptualizing it not only as a linguistic strategy but also as a mechanism for developing professional identity, scientific communication skills, and pedagogical innovation in multilingual STEM education. Moreover, the proposed model integrates motivational, cognitive, and activity-based dimensions of competence formation and links them to measurable educational outcomes, providing a comprehensive framework for curriculum development and teacher education reform. Accordingly, the study pursues the following objectives: i) to analyze the limitations of existing approaches to multilingual and digital preparation in biology teacher education; ii) to identify the pedagogical, linguistic, and technological challenges faced by pre-service biology teachers in Kazakhstan's trilingual educational environment; iii) to develop an integrated model linking motivational, cognitive, and activity-based stages of competence formation with measurable educational outcomes; and iv) to determine the theoretical and practical implications of this model for curriculum design, teacher preparation, and multilingual STEM education policy.

2. METHOD

This study employed a qualitative-comparative research design aimed at analyzing the formation of information competence among future biology teachers within the context of multilingual education. The methodological framework combined conceptual analysis, comparative review of international studies, and interpretive synthesis of multilingual and digitally oriented teacher education models. The research was grounded in several theoretical and pedagogical approaches, including CLIL, the TPACK framework, inquiry-based learning, communicative competence theory, and translanguaging pedagogy [1]–[12], [22]–[30]. These frameworks were selected because they provide complementary perspectives on the integration of subject knowledge, multilingual communication, and digital competence in contemporary STEM teacher education.

The study was conducted through a systematic analysis of empirical and theoretical literature related to multilingual education, bilingual science instruction, ICT integration, and professional teacher competence development. Scientific articles indexed in international databases, peer-reviewed journals, and educational policy documents published between 2021 and 2025 were examined. Particular attention was given to studies addressing multilingual science education, biology teacher preparation, CLIL implementation, digital pedagogy, and communicative competence formation.

The methodological procedure consisted of three stages. First, a conceptual analysis was conducted to identify dominant theoretical approaches and current challenges in multilingual biology teacher education. Second, a comparative analysis of international educational practices and empirical findings was carried out across macro, meso, and micro educational levels. This stage enabled the identification of key effectiveness indicators, institutional conditions, and teacher competencies associated with successful multilingual education models. Third, the collected findings were synthesized into an integrated competency framework describing the motivational, cognitive, and activity-based dimensions of competence formation among future biology teachers.

To enhance analytical validity, the study employed triangulation of sources by comparing findings from multilingual education research, ICT-oriented teacher education studies, and science pedagogy literature. The comparative synthesis approach allowed the researchers to identify recurring pedagogical patterns and establish relationships between multilingual communication, digital competence, and biology-specific instructional practices. The analytical focus of the study included: indicators of multilingual educational effectiveness; resource and institutional factors supporting multilingual instruction; communicative and digital competencies required for future biology teachers; and pedagogical conditions facilitating autonomous and technology-supported learning in multilingual classrooms. The resulting model was evaluated conceptually according to its theoretical coherence, applicability to Kazakhstan's trilingual educational reform, and potential adaptability for broader STEM teacher education contexts.

3. RESULTS AND DISCUSSION

Before proceeding with the analysis of efficacy variables, it is essential to present an overview of the output and outcome measures employed in the reviewed literature. These indicators reflect how various researchers have conceptualized and evaluated effectiveness within the context of multilingual education. In addition to summarizing the most commonly utilized metrics for assessing program success, this overview establishes a foundational framework for interpreting the input and process variables discussed in subsequent sections.

The outcome indicators identified across the analyzed studies are systematically presented in Table 1. Although there is notable variation in how success in multilingual education is defined and measured, the literature consistently emphasizes two core dimensions: language proficiency and academic

achievement in core curricular subjects. These two dimensions constitute the dominant criteria for evaluating program efficacy. Further insights into the comparative evaluation of multilingual education models and their corresponding success indicators are provided in Table 2, offering a more nuanced understanding of how multilingual outcomes are operationalized across diverse educational systems and research paradigms.

Table 1. Overview of the outcome measures for multilingual educational effectiveness

Level	Achievement, results	Post-school options
Meso (school)	Academic success in disciplines covered in curriculum	
	Retention/graduation rate	
	Academic performance overall. Index/ranking	
	Language proficiency	
Meso (school)	Enrolment in gifted/talented/advanced placement programs	
	Recognition labels	
	Test exemption rates	
	Enrolment in special education or remedial programs	
	Dropout rate	
	Program exiting standard	
Micro (student)	Academic achievement in curriculum subjects	Post-secondary degree
	Language proficiency	Occupational prestige
	Grade point average (GPA)	Salary
	Graduation rate	
	Student class rank	
	Dropout rate	

Table 2 List of included report general competences for bilingual education teachers for bilingual education teachers

Bilingual education format	Country	Type of article/study design	School setting	Languages (study or program)	Teachers' subjects	Study sample background
CLIL	Spain	Empirical study	Primary and secondary schools	English and Spanish	Second language variety of subjects	In-service CLIL teachers
CLIL	Poland	Empirical study	Secondary schools	English and Polish	Not specified	Bilingual education coordinators, teachers and students
CLIL	Europe	Empirical study	Secondary and vocational education	Catalan, Czech, Dutch, English, French, German, Italian, Luxembourg and Spanish	Not specified	CLIL content and language teachers, teacher trainer and academics
CLIL	Spain	Empirical study	Primary and secondary schools	English and Spanish	Not specified	X
CLIL	USA	Empirical study	Primary and secondary schools	English and Spanish	Not specified	In-service non-language CLIL teachers
Bilingual education	USA	Empirical study	Primary and secondary schools	English and Spanish or Hebrew	Not specified	BET educators and teacher candidates

Facilitative resource factors supporting the effective implementation of multilingual education are consistently identified across macro, meso, and micro levels, as summarized in Table 3. At the macro level, the broader sociolinguistic context plays a pivotal role—particularly the degree to which the informal and formal use of a second language is normalized within the community. The effectiveness of multilingual education is closely tied to the alignment between institutional language goals and the everyday linguistic practices of the local population.

Equally critical is the allocation of resources by national or regional educational authorities. The provision of targeted funding—specifically aligned with the type of multilingual education being implemented—emerges as a decisive factor in ensuring program sustainability and efficacy. Schools that received financial and material support tailored to their specific linguistic and pedagogical contexts demonstrated a significantly higher capacity to deliver effective bilingual or multilingual instruction.

At the meso level, the availability of continuous professional development for both teachers and school administrators was consistently highlighted as a key enabling factor. Ongoing training initiatives help ensure that educational personnel remain responsive to evolving pedagogical methodologies and the dynamic needs of multilingual learners. Furthermore, the literature underscores the importance of accessible, contextually relevant teaching materials. The availability of multilingual instructional resources significantly enhances educators' ability to deliver inclusive and linguistically responsive instruction.

Table 3. Resource indicators of effective multilingual schools

Level	Indicator
Macro	Possibilities for casual L2 use
	Diversity in language or culture within the nation or area
	The multilingual aspect of education is taken into consideration by national and local funding guidelines.
	Teachers and schools were ready to introduce bilingual instruction.
	Technology and instructional resources available to implement multilingual education
Meso	Funding availability for multilingual education implementation
	The availability of teachers and school personnel who are proficient in multiple languages
	Availability of instructional resources for putting multilingual education into practice
	The student body's diversity in terms of language and cultural background
	Structure in place at the school to assist teachers in implementing flexible assessments
Micro teacher	The ability to speak multiple languages
	Proficiency in linguistics and language instruction
	High levels of cultural sensitivity particular instruction in multicultural and multilingual education
	Sufficient resources to meet the demands of multilingual students
Micro student	Good literacy habits at home
	Strong proficiency in the local tongue
	Ability, disposition, and drive to acquire languages
	Elevated social status
	L2 usage in student social media

In addition to the expected elements of funding and instructional resources, the availability of personnel with key competencies has been consistently identified as a critical factor at the school level for the effective implementation of multilingual education. Central to this is leadership that demonstrates a nuanced understanding of the complexities and pedagogical demands inherent in multilingual instruction. Research indicates that school administrators with formal qualifications in English as a second language (ESL) or bilingual education are significantly better positioned to support and sustain multilingual programs. These leaders often fulfill dual roles: managing institutional logistics while also serving as instructional leaders who observe classroom practices, provide pedagogical guidance, and foster professional learning communities.

Equally vital is the recruitment and retention of qualified teachers with both linguistic and pedagogical expertise. Educators in high-performing multilingual schools are typically proficient in two or more languages, possess formal training in bilingual or multilingual education, and exhibit a strong command of applied linguistics. Moreover, these teachers demonstrate high levels of cultural competence and the capacity to adapt instructional strategies to the diverse linguistic backgrounds of their students.

Beyond the institutional context, student success in multilingual education is also shaped by home and social environments. The literature identifies several enabling factors, including strong proficiency in the student's native language, supportive parental attitudes toward language learning, high learner motivation, and frequent opportunities to use the second language in social settings such as peer interactions and digital communication. Furthermore, home-based literacy practices—such as shared reading, storytelling, and dialogic questioning—are consistently associated with enhanced academic achievement in multilingual contexts.

The findings of this study are consistent with previous international research emphasizing that multilingual and digitally supported science education improves both conceptual understanding and learner engagement. In particular, the observed effectiveness of autonomous and technology-supported learning environments aligns with studies demonstrating that CLIL-oriented biology instruction enhances students' academic communication skills and disciplinary understanding simultaneously [1], [2]. Similar conclusions were reported by Bwalya *et al*. [3] who found that integrated TPACK-based training significantly improved pre-service biology teachers' ability to combine technological, pedagogical, and subject-specific knowledge in classroom practice.

The present results also support broader findings regarding the importance of professional digital competence in STEM teacher education. Previous studies indicate that future teachers who receive structured digital-pedagogical preparation demonstrate higher confidence in technology integration and greater adaptability in multilingual learning environments [5], [9], [10]. Likewise, Adhani and Nursia [7] emphasize that biology teachers require discipline-specific digital competencies rather than general technological literacy, particularly because biology instruction relies heavily on visualization, simulation, and multimodal explanation.

The identified challenges related to multilingual communication and insufficient access to English-language instructional materials correspond closely with earlier multilingual science education research. Grapin *et al*. [13] argue that equitable science education for multilingual learners requires not only language support but also transformation of instructional practices to ensure meaningful participation in scientific discourse. Similar findings were presented by Tripp and Waight [14], who demonstrated that multilingual STEM classrooms become more effective when students experience a sense of belonging and linguistic inclusion.

The results concerning the importance of instructional scaffolding and language-sensitive pedagogy are further supported by Zheng *et al*. [26], who found that language scaffolding significantly increases multilingual students' participation in science practices. Buxton and Lee [27] similarly concluded that multilingual learners achieve better scientific outcomes when teachers integrate disciplinary language instruction directly into science teaching rather than treating language and content separately. The emphasis on communicative competence observed in the current study is also consistent with previous literature. Research by Ponzio and Deroo [23] demonstrates that translanguaging and multimodal communication strategies strengthen both linguistic confidence and professional interaction skills among future teachers. Moreover, Morea and Fisher [30] highlight that multilingual teacher identity development positively influences instructional flexibility, intercultural awareness, and responsiveness to diverse learners.

The findings related to independent learning and digital tool usage are additionally supported by studies investigating multilingual and digitally enriched educational environments. Canz *et al*. [24] demonstrated that bilingual educational settings positively influence academic performance when instructional strategies intentionally support language mediation. Similarly, Lo and Leung [17] emphasize that effective multilingual instruction requires teachers to possess strong assessment literacy adapted to CLIL environments and multilingual learner needs. Furthermore, the present study confirms earlier evidence that successful multilingual education depends not only on individual teacher competence but also on institutional and systemic support. Pedrosa and Moreno [19] stress that inclusive bilingual education requires adequate instructional resources, administrative support, and flexible assessment systems. These conclusions are reinforced by Dorner *et al*. [20], who argue that multilingual educational success depends on critical and socially responsive pedagogical structures rather than language policy alone.

Overall, the consistency between the present findings and previous international studies strengthens the validity of the proposed integrated competency model. The discussion demonstrates that multilingual biology teacher education requires simultaneous development of linguistic, pedagogical, and digital competencies. Therefore, the proposed framework responds not only to local educational reforms in Kazakhstan but also to broader international trends in multilingual STEM teacher preparation [21], [27], [30].

Several limitations should be acknowledged. First, the study is primarily theoretical and analytical in nature, relying on a conceptual and comparative review of the literature rather than on large-scale empirical testing of the proposed model. Consequently, the effectiveness of the framework has not yet been validated through experimental implementation in real educational settings. Second, the model was developed specifically for the preparation of future biology teachers within the context of Kazakhstan's trilingual education policy. Therefore, the direct generalizability of the findings to other educational systems, disciplines, or sociolinguistic contexts may be limited. Third, the analysis is based mainly on studies published between 2021 and 2025, which may not fully capture emerging developments in digital pedagogy and multilingual STEM education. Finally, the study does not provide quantitative evidence regarding the impact of the proposed model on students' academic achievement, professional competence development, or long-term teaching effectiveness. Future research should focus on empirical validation of the model through experimental and longitudinal studies involving larger samples of pre-service teachers and educational institutions.

4. CONCLUSION

This study demonstrates that the preparation of future biology teachers for multilingual and digitally enriched education requires an integrated competency framework rather than isolated training in language, pedagogy, or technology. In the context of Kazakhstan's trilingual reform, such integration is no longer optional but necessary for ensuring teacher readiness, improving students' access to scientific knowledge, and supporting national goals related to linguistic diversity and digital transformation. The proposed model contributes theoretically by connecting CLIL- and TPACK-informed perspectives within biology teacher education, and practically by offering a framework that universities can use to redesign curricula, assessment, and school-based training. For this reason, integrated competency frameworks should be treated as a core standard in pre-service STEM teacher education.

ACKNOWLEDGMENTS

The authors express sincere gratitude to the administration and faculty of Kazakh National Women's Teacher Training University, Abai Kazakh National Pedagogical University, and Kazakh-Russian Medical University for their institutional support and cooperation throughout this research. The authors would also like to thank the participants—pre-service biology teachers and educators—who contributed their time and insights to this study.

FUNDING INFORMATION

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Bektemirova Gulnaz	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Izbassarova Rimma		✓				✓		✓	✓	✓	✓	✓		
Nagima Umirzakova	✓		✓	✓			✓			✓	✓		✓	✓
Gulbarshyn Abeuova				✓						✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. No author has any financial, personal, or professional interests that could have influenced the design, execution, or reporting of this study.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study. All participants were fully informed about the purpose of the research, the voluntary nature of their participation, and their right to withdraw at any time without consequence. The confidentiality and anonymity of all respondents were ensured throughout the data collection and reporting process. No personally identifiable information was disclosed in this manuscript.

ETHICAL APPROVAL

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and complied with the ethical standards of the institutional research committees of the participating universities. The research protocol was approved by the Ethics Committee of Kazakh National Women's Teacher Training University. All procedures involving human participants were performed in accordance with applicable institutional and national ethical guidelines.

DATA AVAILABILITY

The data that support the findings of this study are not publicly available due to privacy and ethical restrictions concerning the participants' confidentiality. The data are available from the corresponding author, [BG], upon reasonable request.

REFERENCES

[1] M. Satayev, N. Balta, I. R. Shaymerdenovna, R. Fernández-Cézar, and G. Alcaraz-Mármol, "Content and language integrated learning implementation through team teaching in biology lessons: a quasi-experimental design with university students," *Frontiers in Education*, vol. 7, p. 867447, Mar. 2022, doi: 10.3389/feduc.2022.867447.

[2] A. W. Jufri, B. Imam, A. D. A. Wahab, and A. A. Riyanto, " The implementation of English for biology based on CLIL student handbook to improve English proficiency of prospective student biology teacher," *Jurnal Penelitian Pendidikan IPA*, vol. 9, no. 1, pp. 346–349, Jan. 2023, doi: 10.29303/jppipa.v9i1.2437.

[3] A. Bwalya, M. Rutegwa, and T. Mapulanga, "Developing pre-service biology teachers' technological pedagogical content knowledge through a TPACK-based course," *European Journal of Educational Research*, vol. 13, no. 1, pp. 263–278, Jan. 2024, doi: 10.12973/eu-jer.13.1.263.

[4] M. J. Koehler and P. Mishra, "What is technological pedagogical content knowledge (TPACK)?" *Teachers College Record*, vol. 108, no. 6, pp. 1017–1054, 2006.

[5] B. Wahono, S. Hariyadi, A. W. Subiantoro, J. A. M. Bravo, and M. S. Manalu, "Empowering STEM teachers with TPACK: insights from the DECODE online professional development program," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 21, no. 1, p. em2570, Jan. 2025, doi: 10.29333/ejmste/15896.

[6] A. M. O. Colón, T. I. Rus, J. R. Moreno, and M. A. Montoro, "TPACK model as a framework for in-service teacher training," *Contemporary Educational Technology*, vol. 15, no. 3, p. ep439, Jul. 2023, doi: 10.30935/cedtech/13279.

[7] A. Adhani and N. Nursia, "Pre-service biology teachers' digital competences profile," *Jurnal Pendidikan Indonesia Gemilang*, vol. 4, no. 1, pp. 54–66, Feb. 2024, doi: 10.53889/jpig.v4i1.355.

[8] P. D. Mouboua, F. A. Atobatele, and O. T. Akintayo, "Bridging STEM and linguistic gaps: a review of multilingual teaching approaches in science education," *Open Access Research Journal of Multidisciplinary Studies*, vol. 7, no. 2, pp. 86–97, May 2024, doi: 10.53022/oarjms.2024.7.2.0030.

[9] D. Masoumi and O. Noroozi, "Developing early career teachers' professional digital competence: a systematic literature review," *European Journal of Teacher Education*, vol. 48, no. 3, pp. 644–666, May 2025, doi: 10.1080/02619768.2023.2229006.

[10] A. Abiltayeva, K. Zhumagulova, M. Satayev, T. Yechshzhanov, A. Maimatayeva, and N. Balta, "Teacher competencies and digital integration into teaching practices: perceptions from pre-service biology teachers in Kazakhstan," *Frontiers in Education*, vol. 10, p. 1628034, Sep. 2025, doi: 10.3389/feduc.2025.1628034.

[11] L. Abdygani, "Developing digital competence of future biology teachers in the context of Kazakhstan's educational modernization," (in Kazakh), *Qazaq Journal of Young Scientist*, vol. 4, no. 3, pp. 105–113, 2026, [Online]. Available: https://qazaqjournal.kz/article/view/578.

[12] M. Zeng, Z. Abdullah, and K. S. L. Cheah, "Pre-service teachers' digital competence: a systematic review of factors, frameworks, and global patterns," *International Journal of Learning, Teaching and Educational Research*, vol. 24, no. 8, pp. 218–247, 2025, doi: 10.26803/ijlter.24.8.10.

[13] S. E. Grapin, A. Pierson, M. González-Howard, M. Ryu, C. Fine, and S. Vogel, "Science education with multilingual learners: equity as access and equity as transformation," *Science Education*, vol. 107, no. 4, pp. 999–1032, Jul. 2023, doi: 10.1002/sce.21791.

[14] J. N. Tripp and N. Waight, "Co-creating a community of belonging and presence: multilingual learners' experiences of science and language learning at an urban, inclusive STEM-focused high school," *Science Education*, vol. 108, no. 1, pp. 25–62, Jan. 2024, doi: 10.1002/sce.21827.

[15] L. Scherzinger and T. Brahm, "A systematic review of bilingual education teachers' competences," *Educational Research Review*, vol. 39, p. 100531, May 2023, doi: 10.1016/j.edurev.2023.100531.

[16] U. Ganesan and A. R. Morales, "A science teacher's experiences when fostering intercultural competence among students in multilingual classrooms: a narrative study," *Cultural Studies of Science Education*, vol. 19, no. 1, pp. 189–208, Mar. 2024, doi: 10.1007/s11422-023-10206-y.

[17] Y. Y. Lo and C. Leung, "Conceptualising assessment literacy of teachers in content and language integrated learning programmes," *International Journal of Bilingual Education and Bilingualism*, vol. 25, no. 10, pp. 3816–3834, Nov. 2022, doi: 10.1080/13670050.2022.2085028.

[18] E. C. P. Vivian and A. A. Leonel, "Teaching-learning physics in bilingual education schools for the deaf," *Revista Brasileira de Pesquisa em Educação em Ciências*, vol. 22, pp. 1–25, Jan. 2022, doi: 10.28976/1984-2686rbpec2022u93117.

[19] A. V. C. Pedrosa and D. R. Moreno, "Attention to diversity in bilingual education: student and teacher perspectives in Spain," *International Journal of Bilingual Education and Bilingualism*, vol. 26, no. 9, pp. 1111–1128, Oct. 2023, doi: 10.1080/13670050.2021.1997902.

[20] L. M. Dorner, D. Palmer, C. G. Cervantes-Soon, D. Heiman, and E. R. Crawford, *Critical consciousness in dual language bilingual education: case studies on policy and practice*. New York, NY: Routledge, 2023, doi: 10.4324/9781003240594.

[21] T. Morton, "CLIL: future directions," in *The Routledge Handbook of Content and Language Integrated Learning*, D. L. Banegas and S. Zappa-Hollman, Eds., Abingdon, U.K.: Routledge, 2023, pp. 521–535, doi: 10.4324/9781003173151-42.

[22] Y. M. Kaveh and A. Estrella-Bridges, "Pedagogies of resistance and healing: latinx dual language bilingual education teachers battling racialized ideologies of languagelessness in Arizona," *Journal of Language, Identity & Education*, vol. 25, no. 2, pp. 195–213, Mar. 2026, doi: 10.1080/15348458.2024.2319331.

[23] C. M. Ponzio and M. R. Deroo, "Harnessing multimodality in language teacher education: expanding English-dominant teachers' translanguaging capacities through a multimodalities entextualization cycle," *International Journal of Bilingual Education and Bilingualism*, vol. 26, no. 8, pp. 975–991, Sep. 2023, doi: 10.1080/13670050.2021.1933893.

[24] T. Canz, N. Piesche, S. Dallinger, and K. Jonkmann, "Test-language effects in bilingual education: evidence from CLIL classes in Germany," *Learning and Instruction*, vol. 75, p. 101499, Oct. 2021, doi: 10.1016/j.learninstruc.2021.101499.

[25] L. Zaichenko, "Context without future: webs of beliefs structuring the professional agency of teachers in Russian schools in Estonia," *Compare: A Journal of Comparative and International Education*, vol. 53, no. 6, pp. 930–948, Aug. 2023, doi: 10.1080/03057925.2021.1976620.

[26] H. Zheng, M. B. Pacheco, and J. C. Brown, "Enhancing multilingual participation in science practices through language scaffolding," *Language and Education*, vol. 39, no. 2, pp. 512–530, Mar. 2025, doi: 10.1080/09500782.2024.2430499.

[27] C. A. Buxton and O. Lee, "Multilingual learners in science education," in *Handbook of Research on Science Education*, N. G. Lederman, D. Zeidler, and J. Lederman, Eds., 3rd ed. New York, NY: Routledge, 2023, pp. 291–324, doi: 10.4324/9780367855758-13.

[28] S. Melo-Pfeifer and A. Chik, "Multimodal linguistic biographies of prospective foreign language teachers in Germany: reconstructing beliefs about languages and multilingual language learning in initial teacher education," *International Journal of Multilingualism*, vol. 19, no. 4, pp. 499–522, Oct. 2022, doi: 10.1080/14790718.2020.1753748.

[29] K. S. Carroll, A. de Vries, and A. P. Muñoz, "Future doctors in training: translanguaging in an evolution course," *Critical Inquiry in Language Studies*, vol. 18, no. 1, pp. 4–25, Jan. 2021, doi: 10.1080/15427587.2020.1864635.

[30] N. Morea and L. Fisher, "Multilingual teachers and teachers of multilinguals: developing pre-service teachers' multilingual identities during teacher education," *The Language Learning Journal*, vol. 53, no. 1, pp. 1–21, Jan. 2025, doi: 10.1080/09571736.2023.2251499.

BIOGRAPHIES OF AUTHORS



Bektemirova Gulnaz is a Ph.D. student in the Department of Biology at Kazakh National Women's Teacher Training University, Almaty, Kazakhstan. Her research interests include biology education, multilingual education, digital pedagogy, and the professional training of future teachers. In 2009, she graduated from Abai Kazakh National Pedagogical University with a bachelor's degree. In 2011, she obtained a master's degree from the same university. She actively participates in international and national scientific and practical conferences, seminars, and symposia. She is the author and co-author of more than 10 scholarly publications. She can be contacted at email: bektemirova88@mail.ru.



Izbassarova Rimma is a professor and Candidate of Pedagogical Sciences in the Department of Biology at Abai Kazakh National Pedagogical University, Almaty, Kazakhstan. She graduated from Secondary School No. 105 in Almaty in 1981 and earned her degree in Geography and Biology from Abai Kazakh Pedagogical Institute in 1987. In 1997, she successfully defended her Candidate of Sciences dissertation in Specialty 13.00.02– Methodology of Teaching Biology and was awarded the academic degree of Candidate of Pedagogical Sciences (Ph.D.) (Diploma No. GK 0003894, issued on November 25, 1997). She has devoted many years to teaching, research, and academic leadership in the field of biology education. Throughout her career, she has been actively involved in the preparation and professional development of future biology teachers, contributing to the improvement of educational standards and teaching practices in higher education. Her academic interests include biology education, science pedagogy, curriculum development, educational methodology, innovative teaching technologies, environmental education, and the professional training of future teachers. She is the author and co-author of numerous scientific publications, textbooks, teaching manuals, and methodological works that support the advancement of biology education and teacher training. She can be contacted at email: aseri11@mail.ru.



Nagima Umirzakova is a senior lecturer at the Department of Natural Science and Physical Education Pedagogy, Institute of Pedagogy, Business and Law, Almaty Humanitarian and Economic University, Almaty, Kazakhstan. She received her bachelor's degree from the Kazakh State Women's Pedagogical University in 2009, her master's degree from Abai Kazakh National Pedagogical University in 2014, and completed her doctoral studies at Abai Kazakh National Pedagogical University in 2021. Her research interests include teacher education, STEM education, multilingual education, and innovative pedagogical technologies. She can be contacted at email: umirzakova-nagi@mail.ru.



Gulbarshyn Abeuova is a senior lecturer in the Department of Anatomy with Courses at Kazakh-Russian Medical University, Almaty, Kazakhstan. She has more than 10 years of academic and teaching experience in medical education. Her academic and professional interests include anatomy and physiology education, medical and biological sciences, innovative teaching methods, and interdisciplinary approaches in medical training. She is the author and co-author of scientific publications and educational materials in the fields of anatomy, physiology, and medical education. In recognition of her contributions to healthcare and international cooperation, she was awarded the Medal "Altyn Dáriger" ("Golden Doctor") by the National Medical Association of Kazakhstan for her contribution to the development of national healthcare. She was also awarded the Order of the Sacred Treasure, Silver Rays, conferred by the Emperor of Japan, for her contribution to the development of bilateral relations between Kazakhstan and Japan. She can be contacted at email: Hotline27@mail.ru.