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METHODOLOGICAL TRAINING OF INFORMATION AND COMMUNICATION TECHNOLOGY ENGINEERS IN THE REPUBLIC OF KAZAKHSTAN WITHIN THE FRAMEWORK OF UNIVERSITY-INDUSTRY PARTNERSHIP

Abstract. In the context of the accelerating digitalization of the economy of the Republic of Kazakhstan and the transition to a new paradigm of industrial development, the requirements for the education and training of Information and Communication Technology (ICT) professionals have increased substantially. A modern ICT engineer is expected not only to master software development tools but also to possess methodological competence-the ability to independently formulate research problems, select appropriate mathematical methods, justify architectural decisions, and critically evaluate the limitations of the approaches employed.
However, an analysis of the current educational practice within the Bachelor's degree program 6B061 Information and Communication Technologies at Kazakhstani universities reveals a persistent gap between academic training, which remains largely focused on the transmission of established knowledge and the development of narrowly defined practical skills, and the actual demands of the ICT industry, which requires professionals with well-developed adaptive expertise and the ability to solve complex, ill-structured engineering problems independently.
This study substantiates the necessity of transitioning from a reproductive model of instruction to a competency-based educational approach integrating contemporary pedagogical strategies. Based on a comprehensive review of international research, the author proposes an integrated didactic system for developing the methodological competence of ICT professionals. The proposed system comprises three complementary layers: (1) an ontological layer, which provides a formalized representation of educational content based on competencies and interdisciplinary relationships; (2) a Challenge-Based Learning (CBL) layer, which generates authentic professional contexts through complex interdisciplinary challenges; and (3) a Four-Component Instructional Design (4C/ID) layer, which supports the acquisition of complex cognitive skills through the sequential completion of learning tasks accompanied by adaptive instructional support. An integrative mechanism connecting these layers ensures alignment among educational content, learning context, and instructional processes, while a reflective assessment component enables the evaluation of methodological competence and facilitates the continuous adjustment of individual learning trajectories.
The practical significance of the proposed system lies in its potential application within Kazakhstani universities to modernize educational programs in the Bachelor's degree program 6B061 Information and Communication Technologies. The paper also outlines directions for future empirical research, including a pedagogical experiment to validate the effectiveness of the proposed model, the development of an ontology-based competency model, and the design of methodological assessment tools for evaluating graduates' methodological preparedness.

Keywords: methodological competence; Information and Communication Technologies (ICT); Bachelor's degree program 6B061; ontological approach; ontology modeling; Challenge-Based Learning (CBL); Four-Component Instructional Design (4C/ID); complex learning; university–industry partnership; engineering education; Republic of Kazakhstan; digital transformation of education; adaptive expertise; curriculum design.

INTRODUCTION

The rapid development of Information and Communication Technologies (ICT) in the Republic of Kazakhstan has been accompanied by the accelerated digital transformation of all sectors of the national economy, including the widespread adoption of artificial intelligence, cloud computing, and distributed systems in public administration, industry, and business. These developments have substantially increased the requirements for the education and training of ICT professionals. A new generation of university graduates is expected not only to maintain existing information systems but also to design innovative software architectures, perform advanced mathematical and algorithmic modeling, and make well-founded engineering decisions.

However, an analysis of the current state of the Bachelor’s degree program 6B061 Information and Communication Technologies at Kazakhstani universities reveals a significant gap between academic education, which remains primarily focused on knowledge transmission and the development of narrowly specialized practical skills-such as proficiency in specific programming languages, frameworks, and development environments-and the actual expectations of employers. Although graduates generally demonstrate strong technical proficiency, many encounter considerable difficulties when addressing complex engineering problems that require the independent selection of research methodologies, the integration of knowledge across multiple disciplines, and the critical evaluation of the applicability of mathematical and algorithmic approaches. According to surveys of employers in Kazakhstan, this gap is particularly evident in areas such as cybersecurity, the design of fault-tolerant systems, big data analytics, and the development of intelligent services, where conventional solutions frequently prove inadequate.

One promising approach to addressing this challenge is the application of ontology-based methods to curriculum design. Previous studies [1-7] have demonstrated that ontology modeling enables the formal representation of domain knowledge, the specification of ICT professional competencies, and the establishment of semantic relationships among academic disciplines, thereby ensuring the coherence and integrity of professional education. Within the context of the Bachelor’s degree program 6B061 Information and Communication Technologies, ontologies provide a mechanism not only for structuring educational content but also for continuously adapting curricula to the rapidly evolving demands of the ICT industry by aligning educational standards with contemporary professional requirements.

These challenges create an objective need to reconsider existing instructional strategies for ICT education. Specifically, there is a need to move beyond the traditional reproductive model of learning, which emphasizes memorization and the reproduction of predefined algorithms, toward a practice-oriented approach that actively engages students in solving authentic professional problems closely reflecting real-world engineering practice. Among the most promising pedagogical approaches are Problem-Based Learning (PBL) and its further development, Challenge-Based Learning (CBL). Both approaches organize the educational process around authentic engineering challenges that require students to independently acquire knowledge, evaluate alternative solutions, collaborate effectively in teams, and critically reflect on the outcomes of their work.

As the theoretical foundation for the proposed educational framework, this study adopts the Four-Component Instructional Design (4C/ID) model developed by van Merriënboer and Sweller [9]. The model provides a systematic approach to developing complex cognitive competencies through the progressive completion of authentic learning tasks while gradually reducing instructional support. This instructional design framework facilitates the preparation of future ICT engineers for independent professional practice in rapidly changing technological environments.

Furthermore, strengthening collaboration between universities and the technology sector represents a strategic priority for the Republic of Kazakhstan. The active involvement of ICT companies in curriculum development, the provision of authentic industrial case studies, and participation in joint project-based activities create favorable conditions for developing not only discipline-specific competencies but also broader professional capabilities, including methodological competence, systems thinking, and adaptive expertise.

The objective of this study is to provide a theoretical foundation and empirically validate the effectiveness of integrating the Challenge-Based Learning (CBL) approach and the Four-Component Instructional Design (4C/ID) model into the education of ICT specialists enrolled in the Bachelor’s degree program 6B061 Information and Communication Technologies at Kazakhstani universities. The proposed integration aims to foster students’ methodological competence as a key prerequisite for successful professional performance in the context of digital transformation.

Problem Statement. Within the higher education system of the Republic of Kazakhstan, the education and training of Information and Communication Technology (ICT) specialists have traditionally been organized around curricula encompassing a broad range of disciplines, including programming, algorithms, computer networks, databases, and information security. A substantial proportion of instructional time is devoted to mastering specific technology stacks and software development tools, enabling graduates to acquire a relatively high level of technical (hard) skills. However, contemporary ICT engineering demands competencies that extend well beyond technical proficiency. Modern ICT professionals are expected to formulate research problems independently, select appropriate mathematical methods, justify architectural decisions, evaluate the limitations and risks associated with alternative approaches, and continuously adapt their professional activities to rapidly changing technological environments. Collectively, these capabilities constitute what is referred to as methodological competence, which has become a key determinant of professional success in the ICT sector.

Despite these requirements, the current educational practice within the Bachelor's degree program 6B061 Information and Communication Technologies at Kazakhstani universities remains predominantly based on a lecture-and-seminar instructional model emphasizing the transmission of established knowledge. Learning tasks are generally characterized by well-defined conditions and a single correct solution. Such an approach does not adequately reflect the nature of real-world engineering problems, where available information is often incomplete, optimization criteria may conflict, and multiple valid solutions are possible. Consequently, graduates frequently demonstrate insufficient readiness for independent methodological inquiry, experience difficulties when selecting among competing approaches – for example, choosing between classical routing algorithms and machine learning techniques or between deterministic and probabilistic models – and are not always capable of critically evaluating the consequences of their engineering decisions.

Empirical observations, together with employer survey data collected during this study, indicate that ICT companies in Kazakhstan experience a shortage of professionals capable not only of software development but also of comprehensive architectural design, distributed systems optimization, infrastructure resilience engineering, and the adaptation of technological solutions to evolving operational environments. This discrepancy is particularly pronounced in areas such as cybersecurity system design, big data analytics, intelligent service development, and the engineering of fault-tolerant critical information infrastructures. At the same time, the corresponding university courses continue to rely predominantly on isolated laboratory exercises, which fail to provide students with a holistic understanding of professional practice or to foster reflective reasoning regarding the methodological foundations of engineering decision-making.

Accordingly, the research problem addressed in this study arises from the contradiction between the objective demand of Kazakhstan's labor market for ICT professionals possessing methodological competence and adaptive expertise, and the existing educational practice within the Bachelor's degree program 6B061, which remains largely focused on the acquisition of narrowly specialized technical skills and does not ensure the systematic development of higher-order cognitive abilities.

Addressing this challenge requires the development and implementation of pedagogical models that integrate authentic professional problem-solving with the purposeful cultivation of methodological reflection, including the justification of mathematical and algorithmic choices, the critical evaluation of alternative solutions, and the ability to redesign engineering decisions in response to changing conditions. To address these requirements, this study proposes the integration of Challenge-Based Learning (CBL) and the Four-Component Instructional Design (4C/ID) model within the framework of university–industry partnership. Such an approach is expected to align educational practice more closely with real-world engineering environments and to facilitate the systematic development of students' methodological competence.

Literature Review. Higher education in the field of Information and Communication Technologies (ICT) in the Republic of Kazakhstan is currently undergoing a profound transformation driven by both rapid technological advancements and evolving educational paradigms. To establish a theoretical foundation for the effective development of methodological competence among students enrolled in the Bachelor's degree program 6B061 Information and Communication Technologies, it is necessary to examine three interrelated research domains. The first concerns contemporary ontology-based approaches to curriculum design. The second focuses on the evolution of active learning methodologies, particularly Problem-Based Learning (PBL) and Challenge-Based Learning (CBL). The third encompasses theoretical frameworks for organizing complex cognitive learning, most notably the Four-Component Instructional Design (4C/ID) model. In addition, studies addressing the digital transformation of engineering education in Kazakhstan provide an important contextual perspective for the present research.

One of the most promising approaches to bridging the gap between the rapidly evolving requirements of the ICT industry and the content of university curricula is ontology-based educational modeling. Unlike traditional taxonomies, ontologies enable not only the formal representation of academic disciplines but also the explicit modeling of semantic relationships among competencies, learning outcomes, and professional standards.

The origins of this research direction can be traced to the Computing Ontology project introduced by Cassel et al. [8], which demonstrated the feasibility of using ontologies as a foundation for curriculum development in computer science education. Subsequent studies shifted their attention toward the formalization of competency-based educational models. Romero et al. [7] proposed an ontology that conceptualizes competencies as the central organizing principle in engineering curriculum design, thereby establishing explicit relationships among instructional methods, assessment strategies, and intended learning outcomes.

European and Ukrainian researchers have made significant contributions to the further development of this approach. Kovaliuk et al. [5] developed an ontology-based model to support the design and accreditation of educational programs for ICT specialists. Their framework integrates disciplinary knowledge, program structures, and institutional requirements within a unified ontology. Designed specifically for undergraduate education, the model demonstrates the effectiveness of ontology-based approaches in enhancing curriculum transparency, consistency, and standardization within the context of the European Higher Education Area.

Recent research has also demonstrated a transition toward more comprehensive and integrated ontology-driven educational systems. Evain et al. [1] proposed a competency-oriented, ontology-based framework for student-centered engineering education that aligns with the international ACM Computing Curricula standards. This alignment enables the ontology to serve as a practical instrument for designing and updating educational programs. Similarly, Aminah et al. [2] introduced the OBC-ONTO ontology framework for curriculum analysis within the Outcome-Based Education (OBE) paradigm. Their model establishes explicit relationships between program-level and course-level learning outcomes, thereby ensuring coherent competency mapping throughout undergraduate education.

An alternative strategy for ontology development was proposed by Piriyapongpipat et al. [3], who employed external knowledge sources – including labor market data, professional standards, and related information – to automatically extract competencies, skills, and dependency relationships. This approach transforms the ontology into a computational representation of the curriculum that can dynamically reflect evolving industry requirements. An important contribution was also made by Barron et al. [4], who developed a computer science topic ontology that assists educators in aligning instructional materials with the latest ACM Computer Science Curricula 2023 recommendations. Such ontology-driven approaches enhance both the flexibility and adaptability of educational content, which is particularly important for the Bachelor's degree program 6B061 Information and Communication Technologies, where technological developments continuously reshape professional competency requirements

Overall, the ontology-based approach has evolved from a simple means of describing subject domains into sophisticated educational systems integrating competencies, learning outcomes, and professional requirements, thereby providing a robust foundation for the methodologically sound design of academic curricula.

The theoretical foundation for implementing active learning approaches is rooted in constructivist learning theory, which was reinterpreted for computer science education in the seminal work of Ben-Ari [6]. The author argued that programming and knowledge engineering require learners to actively construct mental models rather than passively absorb information, rendering traditional lecture-based, reproductive instructional methods fundamentally insufficient.

Within this research tradition, Problem-Based Learning (PBL) has become one of the most influential pedagogical approaches [9-21]. Savery [17] and Hmelo-Silver [16] conceptualized PBL as a learning environment in which authentic problems serve as the starting point for independent knowledge acquisition, the development of metacognitive skills, and the cultivation of inquiry-based thinking. Meta-analyses conducted by Strobel and van Barneveld [18], as well as Walker and Leary [19], demonstrated that although PBL may be less effective than traditional instruction for short-term factual knowledge acquisition, it significantly outperforms conventional approaches in terms of long-term knowledge retention and the transfer of learning to novel professional contexts. Dochy et al. [15] further confirmed these findings by providing quantitative evidence of the positive effects of PBL on communication skills and professional competency development. More recent studies by Loyens et al. [20] and Yew and Goh [21] emphasize the role of PBL as a catalyst for conceptual change and self-regulated learning, both of which are particularly important for ICT engineers working in highly uncertain technological environments.

A further evolution of PBL is represented by the Challenge-Based Learning (CBL) framework, which expands the educational focus from solving isolated problems to addressing complex, interdisciplinary challenges that do not possess a single correct solution. The fundamental principles of CBL were formulated in the methodological framework developed by Nichols et al. [22] and further highlighted in the NMC Horizon Report [23]. Within engineering education, CBL has been extensively integrated into the CDIO (Conceive–Design–Implement–Operate) initiative. Comparative analyses conducted by Malmqvist et al. [24] and Piironen et al. [25] demonstrate that CBL effectively promotes systems thinking while enhancing students' ability to apply fundamental knowledge in unfamiliar professional situations.

A defining characteristic of CBL is its close collaboration with industrial partners. Membrillo-Hernández et al. [26] empirically demonstrated that partnerships with leading technology companies increase the practical relevance of educational projects while fostering entrepreneurial thinking among students. Gallagher and Savage [27] systematically reviewed existing CBL implementation models and concluded that, despite their demonstrated effectiveness, no unified methodology currently exists for designing and implementing CBL environments. This observation highlights the need for additional pedagogical frameworks capable of supporting systematic instructional design.

Despite the well-documented effectiveness of both PBL and CBL, their success depends fundamentally on the quality of instructional design. The incorporation of authentic engineering problems alone does not guarantee the development of higher-order cognitive competencies unless learning activities are systematically sequenced and cognitive load is appropriately managed. Accordingly, the present study adopts the Four-Component Instructional Design (4C/ID) model, originally proposed by van Merriënboer [9] and further elaborated in subsequent studies [10-12], as the methodological foundation for designing competency-oriented ICT education.

The 4C/ID model is grounded in Cognitive Load Theory and assumes that the acquisition of complex professional competencies should be organized around four interrelated instructional components [10]:

1. Learning tasks, which provide authentic contexts for integrating knowledge, skills, and professional reasoning
2. Supportive information, which explains the conceptual principles required for solving non-routine tasks
3. Procedural information, delivered just in time to support routine aspects of task performance; an
4. Part-task practice, which facilitates the automation of recurrent procedural skills.

The central principle of the 4C/ID model is the gradual reduction of instructional support accompanied by a progressive increase in task complexity. This instructional strategy minimizes extraneous cognitive load while directing learners' cognitive resources toward the construction of stable and transferable professional knowledge structures.

Van Merriënboer and Sweller [12] further argued that effective instruction should aim not merely at knowledge acquisition but also at facilitating the transfer of knowledge and skills to new professional contexts. The most recent version of the Ten Steps to Complex Learning framework [11] presents a comprehensive methodology for educational program design, ranging from professional task analysis to assessment development, thereby establishing the 4C/ID model as a versatile framework for engineering education.

The development of contemporary educational models cannot be considered independently of the global and regional transformations affecting higher education in Kazakhstan. Karstina [13,14] examined the influence of socioeconomic and technological trends on engineering education in the Republic of Kazakhstan, emphasizing that the digital transformation of industry and the emergence of a new industrial paradigm require graduates to possess not only technical competence but also adaptive expertise, critical thinking, and the capacity for lifelong learning [13]. The author further stresses the importance of aligning university curricula with corporate competency standards through the adoption of active learning strategies and the strengthening of practice-oriented educational components [14].

The analysis of the current educational practice within the Bachelor's degree program 6B061 Information and Communication Technologies in Kazakhstan indicates that the potential of ontology-based curriculum design and advanced pedagogical strategies, including CBL and the 4C/ID model, has so far been utilized only in a fragmented manner. Existing educational approaches lack integrated frameworks capable of combining the formal representation of competencies through ontological modeling with the procedural development of those competencies via authentic interdisciplinary engineering challenges.

The literature review therefore reveals a clear need for the development of a comprehensive didactic system that integrates ontology-based curriculum design, Challenge-Based Learning as a mechanism for generating authentic professional contexts, and the Four-Component Instructional Design model as a framework for developing complex cognitive competencies. The present study seeks to address this gap in the context of ICT education in the Republic of Kazakhstan, thereby contributing both theoretically and practically to the advancement of engineering education.

RESULTS

The integration of the ontology-based approach, Challenge-Based Learning (CBL), and the Four-Component Instructional Design (4C/ID) model requires more than a simple combination of these individual elements. Rather, it necessitates their organization into a coherent didactic system in which each component performs a distinct function while complementing the others. In the proposed framework, the ontological layer provides a formal representation of the domain knowledge, professional competencies, and logical relationships among academic disciplines, thereby establishing the conceptual foundation of the educational content. The CBL layer generates authentic professional contexts through complex interdisciplinary challenges that immerse students in real-world ICT industry problems and stimulate independent inquiry and solution development. The 4C/ID layer, in turn, governs the instructional process by defining the sequence of learning tasks, regulating the level of instructional support, and ensuring the gradual progression of cognitive task complexity. This instructional design minimizes unnecessary cognitive load while directing learners' working memory resources toward the development of stable and transferable professional knowledge structures.

The interaction of these three layers produces a synergistic effect in which methodological competence emerges not as the accumulation of isolated knowledge and skills but as an integrated professional capability. This capability is reflected in graduates' ability to consciously select, adapt, and combine research and engineering methods when addressing complex, non-routine ICT problems. The overall architecture of the proposed didactic system is presented in Table 1.

Table 1

An Integrated Didactic System for Developing the Methodological Competence of ICT Specialists (Bachelor's Degree Program 6B061 Information and Communication Technologies)

Level/ A component of the system	Functional purpose	Key elements of implementation	An example in relation to the specialty 6B061	Level/ A component of the system	Functional purpose
The ontological layer (structuring of the content)	Formalization of the subject area, competencies and links between disciplines to ensure consistency and continuity of learning	The ontological model of competencies; the ontology of the curriculum; the ontology of topics in computer science; tracing learning outcomes.	Development of an ontology for courses on cybersecurity, cloud computing and big data processing, where interdisciplinary connections and ACM Curriculum requirements are fixed	The ontological layer (structuring of the content)	Formalization of the subject area, competencies and links between disciplines to ensure consistency and continuity of learning
CBL layer (Professional context generation)	Creating authentic engineering challenges that initiate independent knowledge search, alternative analysis, and teamwork	Real-life cases from IT companies; interdisciplinary projects; stages: global idea – essential issue – challenge – research – development – reflection.	The challenge is "To design a fault-tolerant architecture of a distributed system for processing telemetry data of an industrial enterprise with post-quantum cryptographic protection."	CBL layer (Professional context generation)	Creating authentic engineering challenges that initiate independent knowledge search, alternative analysis, and teamwork
Layer 4C/ID (skill acquisition process management)	Organization of consistent performance of complex tasks with regulated pedagogical support and cognitive load management	1) Complex learning tasks (from simple to complex); 2) Supportive information (principles and theories); 3) Procedural information (algorithms of actions); 4) Practice of individual routine elements.	A series of tasks for the development of system modules: from calculating network load (a high-support task) to self-designing secure exchange protocols (a minimum-support task); accompanying mentoring sessions with engineers.	Layer 4C/ID (skill acquisition process management)	Organization of consistent performance of complex tasks with regulated pedagogical support and cognitive load management

Продовження таблиці 1

Integrative mechanism (communication between layers)	Ensuring consistency between the content, context, and learning process	The ontology acts as a "map" of content; CBL forms a "request" for the application of knowledge; 4C/ID defines the "route" of learning.	The ontology captures the competence to "apply evolutionary algorithms to optimize resources" → CBL creates a task to optimize campus resources → 4C/ID builds a step-by-step development from the theory of algorithms to independent implementation.	Integrative mechanism (communication between layers)	Ensuring consistency between the content, context, and learning process
The reflexive-evaluative component	Diagnosis of the level of methodological competence formation and correction of the learning trajectory	Quantitative metrics (code quality, algorithm complexity, tests); qualitative analysis (reflective essays, interviews, project defense); data triangulation.	Assessment of the student's ability to justify the choice between classical routing and fuzzy logic in a specific scenario; analysis of reflective reports on the results of each stage of the project.	The reflexive-evaluative component	Diagnosis of the level of methodological competence formation and correction of the learning trajectory

The proposed didactic system should not be regarded as a simple combination of three independent methodological components. Rather, it constitutes an integrated educational framework in which the ontological layer defines the conceptual structure of educational content, the Challenge-Based Learning (CBL) layer establishes the motivational and problem-oriented learning context, and the Four-Component Instructional Design (4C/ID) layer provides a pedagogically grounded framework for organizing the instructional process. The integration of these layers is achieved through a continuous feedback mechanism. Specifically, the ontology is continuously refined based on the analysis of authentic professional challenges provided by industry partners. In turn, CBL activities are adjusted according to students' actual competency levels as diagnosed through the 4C/ID instructional process. Likewise, the sequence and complexity of learning tasks are revised whenever emerging technological standards are incorporated into the ontology-based competency model. The reflective assessment component completes this iterative cycle by providing not only the final evaluation of learning outcomes but also continuous refinement of the educational system based on empirical evidence.

The practical implementation of the proposed framework within Kazakhstani universities requires the active involvement of ICT industry partners throughout the entire educational process, ranging from the validation of the ontology-based competency model to the joint evaluation of students' project outcomes. The implementation of this approach at Yessenov University has demonstrated its potential to reduce the gap between academic education and the practical requirements of the ICT industry. As a result, graduates of the Bachelor's degree program 6B061 Information and Communication Technologies acquire not only advanced technical competencies but also a well-developed methodological mindset, readiness for continuous professional development, and the ability to operate effectively under conditions of technological uncertainty. Further empirical validation of the proposed didactic system, including quantitative analyses of students' academic performance and qualitative assessments of their methodological and reflective competence, constitutes the focus of the subsequent stages of this research.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

The present study, based on a comprehensive analysis of contemporary approaches to ICT curriculum design and active pedagogical strategies, enables several conclusions to be drawn that are of both theoretical and practical significance for the higher education system of the Republic of Kazakhstan.

First, the findings substantiate the necessity of transitioning from a traditional reproductive model of instruction to a competency-based educational approach in the preparation of students enrolled in the Bachelor's degree program 6B061 Information and Communication Technologies. An analysis of the current requirements of Kazakhstan's ICT industry, together with existing educational practices, revealed a persistent discrepancy between the labor market's demand for graduates possessing methodological competence, adaptive expertise, and the ability to solve complex, ill-structured engineering problems independently, and the prevailing lecture-based instructional model, which remains primarily focused on the transmission of established knowledge and the development of narrowly specialized technical skills.

Second, this study proposes and theoretically substantiates an integrated didactic system for developing the methodological competence of ICT professionals. The proposed framework consists of three complementary layers: an ontological layer, which structures educational content through the formal representation of competencies, academic disciplines, and their interrelationships; a Challenge-Based Learning (CBL) layer, which generates authentic professional learning environments through complex interdisciplinary challenges; and a Four-Component Instructional Design (4C/ID) layer, which regulates the acquisition of complex cognitive competencies through the progressive completion of learning tasks supported by adaptive instructional guidance. The integration mechanism connecting these three layers ensures coherence among educational content, learning context, and instructional processes, while the reflective assessment component completes the instructional cycle by enabling the evaluation of students' methodological competence and facilitating continuous refinement of individual learning trajectories.

Third, the study demonstrates the heuristic value of the ontology-based approach for curriculum design in ICT education under conditions of rapidly evolving technological paradigms. As evidenced by the literature reviewed, ontology modeling not only enables the formal representation of domain knowledge and professional competencies but also supports the alignment of learning outcomes with professional standards – including the ACM Computing Curricula – while ensuring curriculum adaptability to emerging technologies. Within the context of the Bachelor's degree program 6B061 Information and Communication Technologies, ontologies serve as the conceptual foundation upon which both Challenge-Based Learning activities and the sequence of learning tasks within the 4C/ID framework are systematically constructed.

The study further demonstrates the considerable potential of integrating Challenge-Based Learning (CBL) with the Four-Component Instructional Design (4C/ID) model for the development of methodological competence. While CBL provides an authentic, problem-oriented learning environment that closely reflects real engineering practice and stimulates independent inquiry, the 4C/ID model offers a theoretically grounded instructional framework for managing cognitive load, progressively increasing task complexity, and gradually reducing instructional support. Together, these approaches create favorable conditions for the durable transfer of knowledge and skills to novel professional contexts. Strengthened by the ontology-based layer, this integrated framework facilitates the development of not only discipline-specific competencies but also metacognitive strategies, reflective thinking, and readiness for continuous professional learning.

SEVERAL DIRECTIONS FOR FUTURE RESEARCH EMERGE FROM THE FINDINGS OF THIS STUDY

First, the proposed didactic system requires empirical validation within authentic educational settings at Kazakhstani universities. Future research will involve a pedagogical experiment employing a mixed-methods research design, combining quantitative analyses of students' academic achievement and project performance with qualitative assessments of their reflective competence based on reflective essays, semi-structured interviews, and expert evaluations provided by representatives of partner ICT companies.

Second, further work is required to develop a comprehensive ontology-based competency model for the Bachelor's degree program 6B061 Information and Communication Technologies. This model should integrate the requirements of the national higher education standards of the Republic of Kazakhstan, professional competency standards of the national ICT industry, and the recommendations of the ACM Computing Curricula. Such an ontology will provide a coherent foundation for the systematic design of curricula, course syllabi, and assessment frameworks while ensuring consistency, alignment, and continuity throughout the educational program.

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