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A TRIANGULAR CONCEPTUAL MODEL FOR COMPETENCE-ORIENTED TRAINING OF INFORMATICS TEACHERS IN THE AGE OF GENERATIVE ARTIFICIAL INTELLIGENCE: METHODOLOGICAL FOUNDATIONS

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Mardankulov Jasur Amirddinovich
Jizzakh regional center of pedagogical excellence, candidate of pedagogical sciences, associate professor.
Turdaliyev Mansur Normamatovich
Jizzakh regional pedagogical skills center, senior instructor.

Annotation. *The article analyses the theoretical and methodological foundations of competence-oriented education in the training of informatics teachers in the age of generative artificial intelligence (AI). Drawing on a systematic analysis of international scientific concepts (connectivism, TPACK, project-based learning, Education 4.0) and of the works of scholars from the CIS countries and Uzbekistan, the article develops a triangular conceptual model—epistemological transformation, digital transfer of the vitagenic approach, and an innovative-didactic assessment model—and examines its connection to five methodological approaches to competence-based education in informatics: competence-based, systemic, person-oriented, activity-based, and creative. The institutional anchoring of the model in Uzbekistan's regulatory framework and professional development curriculum is shown, and a five-question checklist for auditing professional development programmes is proposed. The model has not yet been tested empirically.*

Key words. *competence-oriented education; theoretical and methodological foundations; epistemological transformation; vitagenic approach; TPACK; connectivism; informatics teacher; artificial intelligence; methodological approaches; professional development; prompt formulation.*

Introduction. Competence-oriented education has become one of the central reference points of educational reform worldwide. In the international literature competence is understood not as a body of knowledge but as the combination of cognitive abilities with the motivational, volitional, and social readiness to use them responsibly in changing situations [11]; the OECD's DeSeCo project grouped key competencies around the interactive use of tools, interaction in heterogeneous groups,

Latin American Journal of Education
www.lajoe.org

and autonomous action[45]. Russian-language scholarship developed its own vocabulary, including the distinction between competence as a set of requirements and competency as the learner's actual possession of it[46]. As a result, the idea of competence-oriented education rests on different theoretical foundations in different scientific schools.

In informatics this diversity is particularly consequential. Informatics is the school subject whose content changes fastest, and the informatics teacher is usually also the school's digital lead, responsible for computational thinking[47] and for colleagues' technological support. Generative AI changes what it means to know the subject: program code and explanatory texts can now be produced on request, so the teacher's professional value shifts from reproducing solutions to formulating problems, critically evaluating machine-generated outputs, and designing learning experiences. The literature on AI in education[48] and UNESCO's competency framework for teachers [14] describe this shift in general terms, but they do not specify what theoretical foundation should underpin the training of informatics teachers in particular.

To bring two earlier theoretical results of the author—the role of the competence-based approach in modernizing digital education and the structure of professional-creative competence—to the practical-methodological level, it is necessary to show which common theoretical and methodological foundation they rely on. Systematizing the diverse theoretical bases of competence-oriented education in the context of informatics education is therefore a separate scientific task.

The aim of the article is to analyse the theoretical and methodological foundations of competence-oriented education in international and local scientific traditions, to synthesize them in the context of training informatics teachers, and to show their institutional consolidation at the practical level. The study asks three questions: (1) which international and CIS/Uzbek theories form the foundation, and what gap remains in them; (2) how the triangular conceptual

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[46]Хуторской А.В. Ключевые компетенции как компонент личностно-ориентированной парадигмы образования // Народное образование. — 2003. — № 2. — С. 58–64 (in Russian). Зимняя И.А. Ключевые компетентности как результативно-целевая основа компетентностного подхода в образовании. — М.: Исследовательский центр проблем качества подготовки специалистов, 2004 (in Russian).

[47]Wing J.M. Computational thinking // Communications of the ACM. — 2006. — Vol. 49, No. 3. — P. 33–35.

[48]Holmes W., Bialik M., Fadel C. Artificial Intelligence in Education: Promises and Implications for Teaching and Learning. — Boston: Center for Curriculum Redesign, 2019. Miao F., Holmes W., Huang R., Zhang H. AI and Education: Guidance for Policy-Makers. — Paris: UNESCO, 2021.

Latin American Journal of Education
www.lajoe.org

model relates to the five methodological approaches; and (3) to what extent the foundation is anchored in Uzbekistan's regulatory and institutional practice.

Research methodology. The study is conceptual (theoretical) and uses four methods. International scientific literature analysis systematized the works of S. Downes, P. Mishra and M. Koehler, J. Larmer, and the documents of the World Economic Forum, selected as the most influential sources on, respectively, networked knowledge, teacher knowledge, project-based learning, and the policy framing of education for the Fourth Industrial Revolution. CIS and local literature analysis examined the works of N.V. Kuzmina, A.K. Markova, E.F. Zeer, M.P. Lapchik, E.K. Khenner, I.V. Robert, V.A. Testov, R.A. Mavlonova, U.Sh. Begimkulov, and others. Content analysis of regulatory documents covered Uzbekistan's decisions on digital education and artificial intelligence. Synthesis was used to adapt and develop the conceptual model proposed in the author's earlier study for a new context. Because the study draws on documents and published theory rather than primary data, its conclusions are theoretical and require empirical verification.

International scientific foundations. Several lines of fundamental research on digital education and project-based teaching have developed in the international context. Connectivism, put forward by S. Downes and G. Siemens, holds that knowledge is built through connections within a network [2; 12]; it has also been criticized for the claim that it is a new learning theory rather than a perspective within existing ones[49]. The TPACK (Technological Pedagogical Content Knowledge) model of P. Mishra and M. Koehler interprets teacher competence as the intersection of three bodies of knowledge—technological, pedagogical, and content knowledge [1]; it extends L. Shulman's notion of pedagogical content knowledge[50], was later supplemented with contextual knowledge[51], and has been re-examined in the light of generative AI [13], while critics point to the blurred boundaries between its components[52]. J. Larmer's work on project-based learning established the learning project as a fundamental means of organizing independent intellectual activity [3],

[49]Kop R., Hill A. Connectivism: Learning theory of the future or vestige of the past? // International Review of Research in Open and Distributed Learning. — 2008. — Vol. 9, No. 3.

[50]Shulman L.S. Those who understand: Knowledge growth in teaching // Educational Researcher. — 1986. — Vol. 15, No. 2. — P. 4–14.

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Latin American Journal of Education
www.lajoe.org

building on a body of research on its effects[53]. The World Economic Forum's "Education 4.0" concept lifts these approaches to the level of public policy and sets the need to rebuild education systems with AI technologies [4][54].

Scientific traditions of the CIS and Uzbekistan. In the scientific school of the CIS countries, the competence-based approach was developed by N.V. Kuzmina, A.K. Markova, and E.F. Zeer as a theory of professional formation [5; 6], and its key-competence formulations by A.V. Khutorskoy and I.A. Zimnyaya[55]; in the methodology of training informatics teachers the works of M.P. Lapchik, E.K. Khenner, and I.V. Robert are especially significant [7]. Among scholars of the Republic, R.A. Mavlonova, N.N. Azizkhodjaeva, and B.Kh. Khodjaev studied the methodology of training pedagogical personnel in the system of continuous education, while the methodology of teaching informatics was substantiated by the scientific schools of A.A. Abdukodirov, M.M. Aripov, U.Sh. Begimkulov, and N.I. Taylakov [8]. The results show that this extensive heritage forms the theoretical foundation, but adapting it to the requirements of the AI era calls for a separate methodological elaboration.

To fill this gap, the triangular conceptual model proposed in the author's earlier study was developed further [10]. The model unites three interrelated directions (Table 1). The first is epistemological transformation: cognition shifts from acquiring ready-made results to independent construction of knowledge[56], and the learner acquires the ability to interact effectively with generative AI—that is, to formulate prompts—which makes the prompt an observable trace of understanding. The second is the digital transfer of the vitagenic approach: according to the theory founded by A.S. Belkin [9], the teacher's life and professional experience becomes the basis of the learning project, which is consistent with the broader tradition of experiential learning[57]. The third is an innovative-didactic assessment model: process and result are assessed together, in line with research on formative assessment[58], through the criteria of technological invariance,

[53]Thomas J.W. A Review of Research on Project-Based Learning. — San Rafael, CA: Autodesk Foundation, 2000.

[54]World Economic Forum. Schools of the Future: Defining New Models of Education for the Fourth Industrial Revolution. — Geneva: WEF, 2020.

[55]See note 2.

[56]von Glasersfeld E. Radical Constructivism: A Way of Knowing and Learning. — London: Falmer Press, 1995.

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Latin American Journal of Education
www.lajoe.org

creativity coefficient, and vitagenic fixation.

Table 1. Vertices of the triangular conceptual model

Vertex of the model	Core idea and theoretical roots	Role of AI	Illustrative practice in teacher training
1. Epistemological transformation	Knowing shifts from acquiring ready-made results to independent construction of knowledge (constructivism; connectivism [2; 12])	Dialogue partner: the quality of the teacher's prompt becomes an indicator of understanding	The teacher solves an algorithmic task, iteratively refines prompts, and verifies the generated solution with tests and counter-examples
2. Digital transfer of the vitagenic approach	The teacher's life and professional experience becomes the basis of the learning project (Belkin [9]; experiential learning)	Assistant: structures, extends and visualizes the experience; does not replace it	The teacher turns an authentic classroom episode into a project, using AI to draft materials that are then adapted to the actual class
3. Innovative-didactic assessment	Process and result are assessed together (formative assessment; project-based learning [3])	Analyst: supports criteria-based analysis of portfolios and project logs; the decision stays with experts	Assessment by three criteria: technological invariance, creativity coefficient, vitagenic fixation

The three criteria of the assessment vertex can be interpreted as follows (a provisional operationalization for further validation). Technological invariance indicates whether the teacher's solution remains sound when the AI tool or model is changed, that is, whether competence belongs to the teacher rather than to a particular tool. The creativity coefficient expresses the share of original contribution relative to the AI-generated baseline; independent expert ratings of the kind used in consensual assessment of creativity[59] are a

[59]Amabile T.M. Social psychology of creativity: A consensual assessment technique // Journal of Personality and Social Psychology. — 1982. — Vol. 43, No. 5. — P. 997–1013.

Latin American Journal of Education
www.lajoe.org

possible measurement basis. Vitagenic fixation requires the teacher's own experience on which the project is built to be documented in the portfolio, which keeps the human source of the work visible.

The study found that the triangular model is closely linked to the five methodological approaches of competence-based education in informatics (Table 2). The competence-based approach moves the learning outcome from "what the teacher knows" to "what the teacher can do"; the systemic approach substantiates the interdependence of components; the person-oriented approach provides an individual development trajectory; the activity-based approach shows that competence is formed only in practical activity; and the creative approach substantiates the need for non-standard pedagogical solutions. Together, these five approaches determine what should be developed (competence-based), in what structure (systemic), tailored to whom (person-oriented), in what process (activity-based), and at what level of quality (creative).

Table 2. Five methodological approaches and their use as a programme-design checklist

Approach	Guiding question	Primary link in the model (proposed)	Checklist item for programme design
Competence-based	What can the teacher do?	Assessment vertex: outcomes expressed as "can do"	Are intended outcomes formulated as observable actions rather than topics covered?
Systemic	In what structure?	All three vertices as interdependent parts	Are content, methods and assessment aligned with one another and with AI use?
Person-oriented	For whom is it tailored?	Vitagenic vertex: the teacher's own experience	Does the programme start from the participants' baseline and prior experience?
Activity-based	In what process?	Epistemological vertex: knowledge constructed through activity	Do participants build and test real products rather than only listen?
Creative	At what level of quality?	Assessment vertex: creativity coefficient	Does the programme require non-standard solutions beyond AI-generated baselines?

Latin American Journal of Education
www.lajoe.org

Institutional anchoring. The institutional consolidation of these theoretical foundations was confirmed through regulatory analysis (Table 3). The general legal basis of the system of continuous professional development of pedagogical personnel is set by Decree PF-6108 and Resolution PQ-4884[60]; its organizational mechanism by Cabinet of Ministers Resolution No. 867[61]; and AI-specific measures by Decree PF-6079 and Resolutions PQ-4996 and PQ-359[62]. In addition, the current professional development curriculum of the Ministry of Preschool and School Education includes "Methodology of Using AI Technologies" as a separate module[63], which shows that the idea of epistemological transformation set out above has received practical recognition at the level of state educational policy.

Table 3. Regulatory and institutional anchoring of the theoretical foundations

Level	Documents	Role in the framework
General legal basis	Decree PF-6108 of 6 Nov 2020; Resolution PQ-4884 of 6 Nov 2020 (education and upbringing system)	Basis of the system of continuous professional development of pedagogical staff
Organizational mechanism	Cabinet of Ministers Resolution No. 867 of 20 Dec 2024	Organizational mechanism of that system
AI-specific measures	Decree PF-6079 of 5 Oct 2020 (Digital Uzbekistan–2030); Resolution PQ-4996 of 17 Feb 2021 (conditions for rapid introduction of AI technologies); Resolution PQ-359	Measures specific to artificial intelligence

[60]Decree of the President of the Republic of Uzbekistan No. PF-6108 of 6 November 2020 "On measures to develop the spheres of education, upbringing and science in the new era of Uzbekistan's development". Resolution of the President of the Republic of Uzbekistan No. PQ-4884 of 6 November 2020 "On additional measures to further improve the education and upbringing system".

[61]Resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 867 of 20 December 2024.

[62]Decree of the President of the Republic of Uzbekistan No. PF-6079 of 5 October 2020 "On approval of the Digital Uzbekistan–2030 Strategy and measures for its effective implementation". Resolution of the President of the Republic of Uzbekistan No. PQ-4996 of 17 February 2021 "On measures to create conditions for the rapid introduction of artificial intelligence technologies". Resolution of the President of the Republic of Uzbekistan No. PQ-359 [date and title to be completed].

[63]Order No. 6 of the Ministry of Preschool and School Education of 8 January 2026, Annex 56.

Latin American Journal of Education
www.lajoe.org

Level	Documents	Role in the framework
Curriculum level	Order No. 6 of the Ministry of Preschool and School Education of 8 Jan 2026 (Annex 56)	Professional development curriculum with the module "Methodology of Using AI Technologies"

Discussion. The results show that, although the theoretical foundations of competence-oriented education are well developed in the international literature (TPACK, connectivism, project-based learning), none of them has specifically studied the organic unity of generative AI and the vitagenic approach in the case of the informatics teacher. TPACK describes what knowledge a teacher needs but not how that knowledge is to be constructed and assessed when a generative model can supply content on demand [13]; connectivism describes networked knowledge but offers few instruments for assessing an individual teacher's competence[64]; project-based learning provides a form of organization but leaves open how the teacher's own experience enters the project [3][65]. This, in turn, demonstrates the independent scientific value of the triangular model proposed by the author: while synthesizing existing theories (the technological-pedagogical intersection of TPACK, the network logic of connectivism, the reliance of vitagenic education on life experience), it unites them in a new way in the context of artificial intelligence.

The practical significance of the results is that each of the five methodological approaches can serve as a separate checkpoint in designing a professional development programme (Table 2): by checking that the programme answers all five questions (what, in what structure, tailored to whom, in what process, at what level of quality), its methodological completeness can be assessed. For example, a programme that only teaches participants to operate AI tools would pass the first question weakly and fail the creative one, since it does not require solutions that go beyond what the tool generates. The same checklist can be used by methodologists when comparing existing courses or when revising the module on AI methodology[66].

Two cautions follow from the literature. First, the introduction of generative AI into teacher training carries known risks—unreliable outputs, privacy of data, algorithmic bias, and over-

[64]See note 5.

[65]See note 9.

[66]See note 19.

Latin American Journal of Education
www.lajoe.org

reliance—which UNESCO's guidance treats as matters of ethics and human oversight [14][67]; the model therefore keeps the teacher and the expert as decision-makers in the assessment vertex. Second, the model should be tested against the strongest criticisms of its sources, in particular the vagueness of TPACK's construct boundaries[68] and the contested theoretical status of connectivism[69]. As a limitation of the study it should be noted that the proposed theoretical and methodological foundation has not yet been tested in practice; this is the task of the following stages of research, which should include expert validation of the criteria and a pedagogical experiment comparing programmes built with and without the checklist.

Conclusion. Thus, the theoretical and methodological foundations of competence-oriented education in the training of informatics teachers were substantiated through a synthesis of international (TPACK, connectivism, project-based learning, Education 4.0) and local (Kuzmina, Zeer, Lapchik, Begimkulov) scientific traditions. The triangular conceptual model proposed in the author's earlier study (epistemological transformation, vitagenic transfer, innovative-didactic assessment) was developed further and organically connected with the five methodological approaches, from which a five-question checklist for designing professional development programmes was derived. The institutional consolidation of the theoretical conclusions was demonstrated using the current regulatory and legal framework of Uzbekistan and the professional development curriculum. This theoretical and methodological foundation will serve as the basis for developing a system and a model for developing informatics teachers' professional-creative competence in the following stages of research.

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[67]See note 4.

[68]See note 8.

[69]See note 5.

Latin American Journal of Education
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13. Mishra P., Warr M., Islam R. TPACK in the age of ChatGPT and generative AI // Journal of Digital Learning in Teacher Education. — 2023. — Vol. 39, No. 4. — P. 235–251.

14. UNESCO. AI Competency Framework for Teachers. — Paris: UNESCO, 2024.