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A Technology For Developing Cognitive Flexibility In Primary School Students Using Generative AI

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Abstract: This article describes the main characteristics of the "4K" model, as well as the technology for the formation and development of cognitive flexibility, communication skills and critical thinking in the school education system.
Keywords: communication, creative thinking, critical thinking, collaboration, "4C" model, soft skills, flexible thinking.

Modern Uzbekistan, in alignment with current trends in the green and digital economies, has defined strategically important directions for the development of the country and society. These trends establish the prerequisites for a qualitative transformation of educational forms and methods, taking into account contemporary societal demands and achievements, thereby laying the foundation for the enhancement of pedagogical theory and practice. The “Uzbekistan-2030” Strategy outlines a series of objectives dedicated to educational system reforms, specifically focusing on elevating general secondary education to a new level, enhancing the status of teaching personnel, and developing their knowledge and qualifications in accordance with international standards[1]. In pedagogical science, it is generally accepted that a teacher's effectiveness is determined by their professionalism, pedagogical mastery, and ability to adapt to the evolving educational information environment. Consequently, teaching methodology becomes the cornerstone for ensuring educational quality, fostering the development of teaching staff, and improving student academic performance.

Modern society necessitates the development not only of academic knowledge but also of personal and meta-subject educational outcomes associated with creative problem-solving, teamwork, and the ability to discern cause-and-effect relationships. One effective instructional model for achieving this is the “4C” framework. This model serves as a framework through which the student develops four core soft skills: creativity, critical thinking, communication, and cooperation (collaboration, or the ability to work in a team). These specific skills are considered essential in modern society; consequently, their development must be integrated into the curricula of schools and kindergartens.

Thus, in fulfillment of one of the objectives of the “Uzbekistan-2030 Strategy” state program—specifically, the development of communication skills, critical and creative thinking, collaboration, and research competencies among general secondary school students—65 new educational publications (comprising textbooks, workbooks, and instructional manuals for teachers based on the “4C” model) are being developed this year[2].

Starting from 2023, the “4C” model has been successfully applied in primary classes. This model first became known in the middle of the last century, and today it is actively promoted in education and professional development. According to this model, the four most in-demand 'soft skills' in the modern world are critical thinking, creativity, communication, and teamwork (collaboration). These skills are universal and can be applied in any field. Therefore, it is of great importance to devote sufficient attention to their development among modern schoolchildren.

Communication is the ability to interact with family, friends, colleagues, and classmates, a skill that fosters success in both personal life and career. It represents the speaker's capacity to establish effective engagement with an audience in order to successfully achieve the objectives of their address. This encompasses the ability to adapt one's speech to the specific context, goals, and needs of the audience, as well

[1]Annex No. 1 to the Decree of the President of the Republic of Uzbekistan dated September 11, 2023, No. DP-158.
[2] **Decree of the President of the Republic of Uzbekistan No. UP-16, dated January 30, 2025.**

ISSN NO: 2770-2367
February, 2026

as the use of various rhetorical devices and techniques to capture the listeners' attention and persuade them of a particular viewpoint.

As a result, students will be empowered to: initiate contact with unfamiliar individuals; engage interlocutors in further interaction; maintain respectful relationships with their social environment; advocate for their positions and safeguard their interests; mitigate the consequences of conflicts; and comprehend others along with the motivations behind their actions.

Well-developed communication skills are manifested in the ability to articulate thoughts clearly, listen attentively, and comprehend others, as well as the capacity to interact effectively across various situations. These skills encompass not only verbal discourse but also the utilization of non-verbal cues, such as body language and facial expressions. Furthermore, they involve the ability to cultivate a comfortable and trusting atmosphere for interaction, thereby facilitating enhanced communication and mutual understanding.

Creativity is the capacity to generate novel ideas, identify unconventional solutions, and apply innovative approaches to problem-solving. This skill enables individuals to develop cognitive flexibility, enhancing their ability to recognize unique opportunities and explore alternative pathways. It represents the ability to perceive things differently from others, propose original solutions and ideas, and think broadly, globally, and creatively. Creativity arises at the intersection of an individual's intellectual and creative faculties and is a skill that can be actively cultivated. In the current landscape, creative thinking has emerged as a paramount 'soft skill,' as creative individuals are capable of developing fundamentally new, high-value products and identifying the effective solutions so essential to the modern world.

Well-developed creative skills are characterized by the capacity to generate unconventional and valuable ideas, along with the proficiency to bring them to fruition. The core indicators of advanced creative thinking include fluency, flexibility, originality, and elaboration (the ability to detail and refine ideas).

Teamwork (collaboration) is currently seeing the active development of so-called “networking” or “beneficial connections”, where individuals leverage their acquaintances and their respective professional networks to solve complex professional, personal, and social challenges. Furthermore, social interaction fosters personal growth and self-discovery; through it, individuals acquire new knowledge and insights about themselves and the world, leading to personal enrichment. Well-developed communication skills facilitate cooperation—the ability to work effectively in a team and competently utilize the collective knowledge and skills of its members. Collaboration is indispensable across all spheres. In an educational context, it is vital for joint projects, brainstorming sessions, and preparation for assessments.

The implementation of the “4C” model into primary school teaching methodologies has demonstrated that the development of critical thinking, creativity, communication, and collaboration is a priority for the majority of educators. They instruct students on how to work both independently and within a team, while fostering a creative approach to any given challenge.

Critical thinking is the ability to analyze information, navigate complex problems, and make well-founded decisions. It facilitates the development of logical reasoning, the assessment of evidence and arguments, and the cultivation of a critical stance toward information.

The American philosopher and educator John Dewey posited that reflective thinking—understood in the modern context as critical thinking—should constitute the foundation of education[3]. Advanced creative thinking is characterized by a range of indicators, including flexibility, originality, fluency, elaboration, resistance to premature closure, and abstract thinking. It involves the ability to generate novel, unconventional, and unexpected ideas that transcend established patterns, the capacity to discern interconnections between disparate phenomena and concepts, and the abandonment of habitual stereotypes and traditional problem-solving approaches.

Nevertheless, questions regarding the development and assessment of critical thinking persist: how should it be fostered (through which methodologies), and how should it be evaluated (using what instruments and criteria)?

[3] Kennedy, M., Fisher, M. B., & Ennis, R. H. (1991). Critical Thinking: Literature Review and Needed Research. In L. Idol & B. P. Jones (Eds.), Educational Values and Cognitive Instruction: Implications for Reform. Hillsdale, NJ: Lawrence Erlbaum Associates. Available at: https://www.scirp.org/reference/referencespapers?referenceid=1300924 (Accessed June 16, 2025).

ISSN NO: 2770-2367
February, 2026

In discussing the methodology for fostering and developing critical thinking, it is essential to highlight the educational framework for critical thinking development, which prioritizes three core stages: Evocation, Realization of Meaning, and Reflection.

Evocation constitutes the first stage of the instructional framework for critical thinking development. Its objective is to activate prior knowledge on the subject, stimulate interest, and facilitate the recognition of knowledge gaps. During this phase, students recall their existing information, formulate questions, and are motivated toward active engagement and the pursuit of new information[4].

Realization of Meaning is the process of assigning sense to everything an individual learns and experiences, as well as a reflective activity aimed at analyzing and enhancing one's own cognitive processes. During the realization phase, learners analyze, systematize, and draw conclusions, correlating new information with previously acquired knowledge. This process facilitates the development of students' personal perspectives and attitudes toward the subject matter. Furthermore, at the 'Realization of Meaning' stage, students independently pose questions and seek to discover the answers[5].

Reflection is self-analysis and the comprehension of one's own cognitive processes. It is the ability to view one's thinking from an external perspective and analyze its content, effectiveness, and results, thereby enabling the adjustment of one's beliefs and actions[6].

In educational and developmental psychology, the concept of reflection is most frequently examined in connection with the study of students' learning activities:

- ✓ According to V.V. Davydov, reflection is the ability of students to identify, analyze, and correlate their own methods of learning activity with the subject-matter situation—a specific skill for evaluating the potential of one's actions from the perspective of the plans and programs of the learning activity itself.
- ✓ According to N.F. Talyzina, reflection is an individual's ability to be conscious of their actions and to provide arguments and justifications for their activity.
- ✓ In the view of V.V. Kraevsky and A.V. Khutorskoy, reflection is the awareness of the methods of activity, the discovery of its semantic characteristics, and the identification of the educational advancements (increments) of the student or teacher. The student becomes conscious not only of what has been achieved but also of the methods of activity—that is, how it was accomplished.

This educational framework was developed by American educators J. Steele, K. Meredith, and C. Temple, representing the 'Reading and Writing for Critical Thinking' (RWCT) pedagogical technology. The structure of this framework is coherent and logical, as its stages correspond to the inherent phases of an individual's cognitive activity. The table below presents a precise instructional algorithm for a lesson (or a series of lessons), while the practical layer consists of a set of techniques and lesson strategies, along with recommendations for their application at specific stages (Tables 1 and 2).

Table 1
Technological Stages

Stage 1	Stage 2	Stage 3
Evocation: ✓ Prior knowledge; ✓ Interest in obtaining new information; ✓ Student setting of their own learning goals;	Realization of Meaning: ✓ Obtaining new information; ✓ Student adjustment of set learning goals;	Reflection: ✓ Reflection, birth of new knowledge ✓ Student setting of new learning goals

[4] Verevkina, I. N. (2017). The "evocation" phase in the technology of critical thinking development and its techniques in history lessons. In Aspects and Trends of Pedagogical Science: Materials of the III International Scientific Conference (St. Petersburg, December 2017) (pp. 97-99). St. Petersburg: Svoe Izdatelstvo. URL: https://moluch.ru/conf/ped/archive/273/13259.

[5] Zair-Bek, S. I., & Mushtavinskaya, I. V. (2011). *Developing Critical Thinking in the Classroom: A Handbook for Teachers of General Education Institutions* (2nd ed., rev.). Moscow: Prosveshcheniye. 223 p. (Working under the New Standards). ISBN 978-5-09-019218-7.

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ISSN NO: 2770-2367
February, 2026

Table 2

Critical Thinking Development Technology: Stages and Instructional Techniques (according to S.I. Zair-Bek and I.V. Mushtavinskaya)

Stage (Phase)	Teacher's Activity	Students' Activity	Possible Techniques and Methods
I. Evocation (Anticipation)	Focused on eliciting students' prior knowledge regarding the topic, activating their engagement, and motivating them for further work.	The student recalls existing knowledge on the subject (makes assumptions), systematizes information before studying it, and poses questions they would like to have answered.	✓ Listing known information; ✓ Story-prediction based on keywords; ✓ Graphic systematization: clusters, tables; ✓ True and false statements; ✓ Scrambled logical chains, etc.
Information obtained during the evocation stage is heard, recorded, and discussed. Work is conducted individually, in pairs, and in groups.			
II. Realization of Meaning	Aimed at maintaining interest in the topic during direct engagement with new information; facilitating a gradual progression from old knowledge to new.	The student reads the text (listens), utilizing active reading methods proposed by the teacher; makes notes in the margins or keeps records as they internalize new information.	Active reading methods: ✓ marking with symbols "V", "+", "–", "?" (placed in the right margins while reading); ✓ Maintaining various records such as double-entry journals or learning logs; ✓ Seeking answers to questions posed in the first part of the lesson, etc.
During the realization of meaning stage, direct engagement with the information occurs (via text, film, lecture, or textbook material). Work with the new information is conducted either individually or in pairs			
III. Reflection	The teacher guides students back to their initial notes and assumptions to make changes or additions, and provides creative, research, or practical tasks based on the learned information.	Students correlate "new" information with "old" information, utilizing the knowledge acquired during the realization stage.	✓ Filling clusters and tables; ✓ Establishing cause-and-effect relationships between information blocks; ✓ Returning to keywords, "True" and "False" statements; ✓ Answering posed questions; organizing oral and written roundtables; ✓ Organizing various types of discussions; ✓ Writing creative works; ✓ Researching specific questions within the topic, etc.
At the reflection stage, creative reprocessing, analysis, and interpretation of the studied information are performed. The work is carried out individually, in pairs, or in groups.			

ISSN NO: 2770-2367
February, 2026

A frequent explanation for the lack of instructional effectiveness is that teachers often design the learning process based solely on their own predetermined objectives, assuming these will be inherently internalized by students as their personal goals. This approach enables a more precise structuring of instructional stages and the definition of performance criteria and diagnostic methods. However, many prominent educational scholars associated with the constructivist paradigm (e.g., J. Dewey, B. Bloom) contend that students must be granted the opportunity to establish their own learning objectives. Only after this stage can the educator select effective methodologies to achieve these objectives. It is worth noting that individuals assimilate information most effectively when it relates to a topic with which they are already familiar. When is decision-making most accessible? It is when our actions align with existing experience, even if that connection is indirect. Thus, providing students with the opportunity to analyze their prior knowledge on a subject creates a significant incentive for the formulation of their own intrinsic **goal-motives**. It is precisely this objective that is addressed during the **evocation stage**. Another task of this phase is the **activation of student engagement**. It is frequently observed that some students exert minimal intellectual effort during lessons, preferring to wait until others resolve the proposed task. Consequently, it is vital for every student to participate in activities aimed at the **activation of their personal experience**. This can be achieved by combining individual and group work techniques. For instance, students can be asked to recall what is already known about the topic and record it as **keywords**; they then share their findings in pairs or groups to compile a collective list, followed by a comprehensive discussion with the teacher.[7]

Thus, during the implementation of the evocation stage, it is essential to:

1) Provide students with the opportunity to express their perspectives on the subject matter freely, without fear of making mistakes or being subjected to immediate correction by the teacher.

2) Record all statements: every contribution is significant for subsequent work. At this stage, there are no "right" or "wrong" responses.

3) Integrate individual and group work: individual activities allow each student to activate their own knowledge and experience; group work enables them to hear diverse opinions and articulate their viewpoints without the risk of being incorrect. The exchange of perspectives can facilitate the generation of novel ideas that are frequently both unconventional and productive; it also fosters the emergence of intriguing questions, the pursuit of which serves as a motivational catalyst for engaging with new material. Furthermore, students often experience apprehension when expressing viewpoints directly to the teacher or within a large-group setting; consequently, small-group interactions provide a more secure and comfortable environment for participation. At this stage, the educator's role is to stimulate the retrieval of prior knowledge, facilitate constructive dialogue within groups, and assist in the systematic recording of student-generated information. Critically, the teacher must refrain from criticizing student responses, regardless of their accuracy or precision. The governing principle at this phase is: "Every student's opinion is valuable".

C. Temple, K. Meredith, and J. Steele identified a series of essential conditions for educators that, when implemented, facilitate the development of critical thinking in students:

1. Allocate sufficient time and opportunity for students to gain practical experience in critical thinking.
2. Grant students the opportunity to reflect on the material being studied.
3. Accept and value diverse opinions and ideas, fostering an environment of intellectual pluralism.
4. Promote active student engagement throughout the instructional process.
5. Ensure psychological safety by convincing students that they run no risk of being ridiculed for their contributions.
6. Express confidence in the ability of every student to make sound critical judgments.
7. Demonstrate a genuine appreciation for manifestations of critical thinking.

Correspondingly, students are expected to:

[7] Zair-Bek, S. I., & Mushtavinskaya, I. V. (2011). Developing Critical Thinking in the Classroom: A Handbook for Teachers of General Education Institutions (2nd ed., rev.). Moscow: Prosveshcheniye. 223 p. (Working under the New Standards). ISBN 978-5-09-019218-7.

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February, 2026

1. Develop self-confidence and an appreciation for the intrinsic value of their own opinions and ideas.
2. Engage actively in the instructional process.
3. Listen respectfully to diverse perspectives and alternative viewpoints.
4. Be prepared both to articulate their own judgments and to withhold them when further information is required.

In instances where the subject matter is unfamiliar, or students lack sufficient prior knowledge and experience to form sound conclusions, they should be invited to offer hypotheses or predictions regarding the potential object of study. The successful implementation of the evocation stage generates a powerful impetus for the subsequent phase—the acquisition of new information.

The Realization of Meaning stage may also be referred to as the semantic phase. Most frequently, the introduction to new information occurs through teacher instruction; significantly less often, it happens through reading or viewing materials via video or computer. During the implementation of the semantic stage, students engage directly with new information. A key condition for the development of critical thinking is the monitoring of a student's comprehension of the subject matter. Indeed, this monitoring is the primary task of the instructional process during the realization of meaning stage. A crucial aspect of this stage is the acquisition of new information regarding the topic. Given that students identified their own directions of cognition during the evocation stage, the teacher has the opportunity to emphasize specific points during the explanation of new material, aligning them with students' expectations and the questions they posed. The organization of work at this stage can vary significantly and may include: a lecture, a teacher's narrative, or individual, pair, or group reading/viewing of video materials. Regardless of the format, the focus remains on individual reception and the tracking of information. Throughout the semantic stage, the primary objective is to sustain student engagement, interest, and the momentum (inertia) generated during the evocation phase. Consequently, the quality of the selected instructional material is of paramount importance.

During the realization of meaning stage, students:

1. Engage directly with new information.
2. Attempt to correlate this information with their prior knowledge and experience.
3. Focus their attention on seeking answers to previously identified questions and difficulties.
4. Identify ambiguities while attempting to formulate new questions.
5. Strive to monitor the actual process of engaging with new information, noting what captures their attention and identifying which aspects are less engaging and why.
6. Prepare to analyze and discuss the material they have heard or read.

At this stage, the teacher:

- ✓ Serves as a direct source of new information, where the primary objective is to present the material in a clear and compelling manner.
- ✓ Monitors the levels of engagement and attentiveness during the reading or viewing process.
- ✓ Introduces various techniques designed to facilitate close reading and critical reflection on the material[8].

Reflection Stage. R. Bustrom notes: "Reflective thinking means focusing your attention. It means careful weighing, evaluation, and selection." In the process of reflection, the information that was new becomes appropriated and is transformed into one's own knowledge. Analyzing the functions of the first two stages of the critical thinking development technology, it can be concluded that, in essence, reflective analysis and evaluation permeate all stages of work. At the same time, reflection during the stages of evocation and realization of content has different forms and functions. In the third stage of the process, reflection becomes the main goal of the activity for both students and the teacher.

Work at the stage of realization of meaning is individual. Students familiarize themselves with new material. In this process, for each of them, this occurs in accordance with the set goals and the questions and

[8] Zair-Bek, S. I., & Mushtavinskaya, I. V. (2011). Developing Critical Thinking in the Classroom: A Handbook for Teachers of General Education Institutions (2nd ed., rev.). Moscow: Prosveshcheniye. 223 p. (Working under the New Standards). ISBN 978-5-09-019218-7.

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difficulties that arose during the first stage. Reflective analysis is aimed at clarifying the meaning of the new material and constructing a further learning path (this is clear, this is unclear, it is necessary to learn more about this, it would be better to ask a question about this, etc.).

Reflective thinking can be formed at the very beginning of schooling, where a system of scientific concepts serves as the material of learning activity, instructional models act as the means, and it is carried out in the form of instructional collaboration. The core content consists of reflective knowledge as general methods for solving a certain class of problems, the boundaries of which are defined by the learner themselves.

In this regard, generative artificial intelligence (AI) can serve as one of the assistants[9].

Generative AI facilitates the development of students' flexible thinking (cognitive flexibility), enabling them to switch between different perspectives and adapt to new conditions.

The main methods of impact are highlighted as follows:

Generation of alternatives and brainstorming: AI assists students in finding multiple solutions to a single task, refining objectives, and actualizing ideas, thereby teaching them to recognize more than one 'correct' answer.

Stimulation of critical analysis: neural networks can generate counterarguments, probing questions, and discussion topics. Students learn to filter and integrate AI-generated content, which develops their analysis and synthesis skills.

Simulation of real-world scenarios: AI enables the modeling of situations in which students must make decisions and solve problems within a dynamic context, preparing them for uncertainty.

Personalization and Adaptability: AI adapts educational curricula to individual paces and styles of perception. This encourages students to be flexible in their choice of learning strategies.

Visualization of Abstractions: The ability of AI to instantly transform conceptual ideas into images or text helps students better understand and connect complex abstract ideas.

Case Study Example: "Emotional Intelligence as a Life Skill"

This case study was developed with the assistance of generative AI.

“Act as an expert in soft skills development and a Socratic teacher. Our topic is 'Emotional Intelligence (EQ) as a key 21st-century skill.”

Your task is to conduct a cognitive flexibility exercise with me in 3 stages:"

“Advocate” Stage: Provide a compelling argument why high EQ is more important for future careers than academic knowledge (IQ) and technical skills. Ask if I agree and why.

“Skeptic” Stage: After my response, sharply switch positions. Provide a counterargument: why in the age of AI and automation, only cold calculation and hard skills matter, and the emphasis on EQ is merely a temporary fad. Ask me to defend the EQ position against your new arguments.

"Synthesis" Stage: Suggest that I conceive of a future profession where success is unattainable with only one of these skill sets.

How This Develops Cognitive Flexibility in Students?

Overcoming "Tunnel Vision": Students often tend to agree immediately that EQ is beneficial. AI, by acting as a "Skeptic," forces them to seek profound arguments rather than relying on superficial clichés.

Empathy for the Opposing Position: To respond effectively to the "Skeptic," the student must momentarily adopt an alternative perspective and understand the logic of an individual who values only figures and facts.

[9] Alier, Marc, Francisco García-Peñalvo, and Jorge D. Camba. "Generative Artificial Intelligence in Education: From Deceptive to Disruptive." (2024)

ISSN NO: 2770-2367
February, 2026

Working Under Conditions of Uncertainty: When the AI "sharply switches positions," the student's brain experiences a micro-stress from the abrupt change in context. The ability to quickly adapt and sustain a logical discussion constitutes the actual training for cognitive flexibility.

Classroom Mini-Case:

Divide the class into groups. One group works with the AI in "Optimist" mode, and the second group works in "Skeptic" mode. At the end of the lesson, they must combine the results and create a "Competency Map of the Ideal Specialist of 2030.

This case study transforms passive information consumption into active inquiry.

1. It promotes the development of critical thinking skills. Working in polar modes ("Optimist" vs. "Skeptic") eliminates confirmation bias—the tendency to seek only information that aligns with one's own opinion. Students come to understand that any technology or phenomenon (in this case, AI and EQ) is not an "absolute good" or "absolute evil," but a set of opportunities and risks. As a result, students master the ability to recognize nuances instead of relying on black-and-white thinking.

2. Cognitive flexibility is practiced. The most critical stage occurs at the conclusion—when consolidating the results. Students are required not merely to defend their own viewpoints but to integrate external, often opposing perspectives into a unified system (the Competency Map). Consequently, this fosters the ability to synthesize contradictory information and identify a viable compromise.

3. Information literacy (AI Literacy) is developed. The case study teaches how to interact correctly with a neural network as a tool. Students learn to quickly notice that AI provides different responses depending on the assigned role (prompt). As a result, an understanding emerges that 90% of the outcome of working with AI depends on the angle from which the question is posed.

4. Communication and teamwork are enhanced. Developing a shared "Competency Map" serves as a collaborative exercise. This results from “Skeptics” and “Optimists” being compelled to engage in negotiations. "Optimists" contribute a vision of the future, while "Skeptics" provide requirements for safety and skill reliability. This culminates in the development of skills for constructive dialogue and co-creation.

Developing this case study required less than one minute with the proper formulation of a prompt. This circumstance demonstrates that generative artificial intelligence is becoming a 'smart assistant' for the teacher, taking over routine tasks and enhancing creative potential. Generative AI ensures the instantaneous creation of content, and the teacher can obtain interactive assignments, quizzes, dictation texts, and problems of various difficulty levels in seconds. What previously took hours now requires only minutes.

Furthermore, by utilizing generative AI, teachers can rapidly adapt the same material for different students, as well as create role-playing models and simulations. One of the advantages of generative AI is the reduction of the risk of professional burnout for teachers, as AI assumes the responsibility for developing methodological resources.

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ISSN NO: 2770-2367
February, 2026

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