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THEORETICAL FOUNDATIONS OF DEVELOPING COGNITIVE COMPETENCY THROUGH TRILINGUAL SOFTWARE IN MATHEMATICS LESSONS

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Abstract
This article presents the theoretical foundations for developing students' cognitive competencies through the use of trilingual software in mathematics lessons. It analyzes the impact of educational software on cognitive development, the opportunities for trilingual (Uzbek, Russian, and English) instruction, and the role of trilingual technologies in fostering thinking, analytical reasoning, and problem-solving skills.

Keywords: Semantic analysis, metacognition, functional context, analytical thinking, didactic function, digital education, software platform, modular learning, QR-coded task, blended learning, divergent thinking, GeoGebra, Desmos, Khan Academy.

Introduction
In today's era of globalization, modern forms of education — particularly digital and multilingual (trilingual) technologies — are becoming increasingly relevant for deepening students' knowledge. At the academic lyceum level, effective teaching of mathematics, developing students' thinking skills, and fostering analytical reasoning require the implementation of modern methodological approaches.

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Cognitive competence refers to a set of abilities that includes acquiring, storing, analyzing, and applying knowledge in practice. Mathematics plays a special role in developing these competencies due to its inherent logical and analytical nature. In this process, trilingual educational software (such as GeoGebra, Desmos, Khan Academy, etc.) serves as an important tool for supporting students' cognitive development.

In psychological and pedagogical literature, cognitive competence is viewed as a concept associated with conscious activity, thinking, understanding, memorization, and problem-solving skills. The development of this competence in academic lyceum students occurs through the following stages:

- Comprehension and assimilation of knowledge;
- Analysis of information and identification of logical connections;
- Acquisition of new knowledge through solving problem-based tasks.

Trilingual software refers to a set of educational programs that operate in Uzbek, Russian, and English languages, which not only support academic learning but also contribute to students' linguistic development. Such tools enhance cognitive development through the following mechanisms:

- Expanding thinking by comparing mathematical concepts explained in different languages;
- Demonstrating various approaches to solving problem-based situations;
- Encouraging independent learning through multilingual interactive resources in mathematics.

A theoretical model for developing cognitive competence through trilingual software can be proposed as follows:

Component	**Description**
Language Component	Basic mathematical terms and tasks in Uzbek, Russian, and English languages
Cognitive Component	Thinking, analysis, synthesis, comparison, problem-solving
Digital Component	Working with tools like GeoGebra, Desmos, Maple, Khan Academy, etc.

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Based on this model, the student simultaneously reads, comprehends, analyzes, and tests tasks in three languages. This process forms interconnections in the brain and ensures the conscious assimilation of knowledge.

Cognitive competence is a set of knowledge and skills that includes a student's ability to perceive, understand, retain, analyze, synthesize, and adapt information to new situations. According to research by international organizations such as **UNESCO** and **OECD**, cognitive competence is among the leading key competencies that students must develop in the 21st century.

Cognitive competence consists of the following components:

- **Perception of knowledge**: understanding and processing mathematical information;
- **Logical thinking**: expressing mathematical reasoning and drawing conclusions from formulas;
- **Analysis and comparison**: comparing mathematical objects, graphs, and algebraic expressions;
- **Problem-solving in complex situations**: applying strategic thinking in uncertain or challenging contexts.

These competencies are reinforced specifically within the content of mathematics, as mathematics is a discipline that inherently requires logic, analysis, and structural thinking.

Trilingual software refers to digital tools that enable students to engage with interactive mathematics instruction in Uzbek, Russian, and English. These platforms typically include:

- **GeoGebra** – visual modeling in algebra, geometry, and calculus;
- **Khan Academy** – interactive video lessons for learning mathematics (available in multiple languages);
- **Desmos** – solving equations and performing graph analysis interactively;
- **Maple, WolframAlpha** – working with complex expressions and mathematical systems.

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Advantages of trilingual platforms include:

- The ability to view each topic in three languages enhances **cognitive flexibility**;
- Visual tools in a digital environment help students **acquire and retain information more effectively**;
- Strengthens students' skills in **independent study and inquiry**;
- **Interactivity in lessons** increases motivation and active participation.

Multilingualism (trilingualism) is not only a tool for developing language competence but also an effective means of enhancing **cognitive adaptability**, **reasoning**, and **analytical thinking**. Learning a single mathematical concept in three languages:

- Enhances students' ability for **semantic analysis**;
- Enables the identification of **logical connections** by comparing different definitions and explanations;
- Encourages **divergent thinking** by expressing ideas in multiple ways;
- Reinforces **analytical thinking** through the expressive features of each language.

Below are the key **didactic functions** of trilingual platforms:

Function	**Example (GeoGebra)**	**Impact on Cognitive Competence**
Visualization	Drawing graphs	Understanding through visual perception, connecting concepts
Interactivity	Real-time manipulation of equation outcomes	Analytical thinking, understanding cause-and-effect relationships
Automated analysis	Exploring parameter changes in Desmos	Searching for alternative solutions, conducting experiments
Language switching	Studying the same topic in three languages	Comparing ideas, identifying logical structures through language

For example, explaining the concept of a **parabola** by plotting its graph in **Uzbek** using GeoGebra, expressing it through a **formula** in **Russian**, and providing a **verbal explanation** in **English** activates the student's multi-dimensional perception mechanisms.

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Through these tools, students not only arrive at the correct result but also learn to deeply **analyze the process**, **distinguish cause and effect**, and **justify their reasoning**.

The use of trilingual software in academic lyceums is proposed in the following formats:

- **Modular instruction**: Each module is developed in three languages;
- **QR-coded tasks**: Students scan the code and independently solve the problem on the platform;
- **Blended learning**: A combination of in-class and online digital instruction;
- **Scenario-based problem tasks**: Trilingual problem-solving cases that promote student inquiry.

These strategies **enhance classroom engagement**, **increase student participation**, and most importantly, **strengthen cognitive competencies**.

In order to conduct a deeper theoretical analysis of cognitive competence development, the views of leading scholars in modern **pedagogy**, **psychology**, and **digital education** serve as key reference points.

One such scholar is **J.R. Anderson (USA)** — founder of **cognitive process theory**.

According to **J.R. Anderson (USA)**, the process of knowledge acquisition occurs in three stages: receiving information, processing it logically, and applying it in new contexts. He emphasizes that **modeling cognitive activity** can deepen understanding. This approach is enhanced through **trilingual software**, where students grasp concepts in three languages and represent them visually through graphs or algebraically, thereby reinforcing comprehension.

V.I. Baydenko (Russia) — proponent of the **competency-based approach**
Baydenko argues that true competence is demonstrated by a student's ability to **apply knowledge in practice**. He highlights the importance of **independent activity, inquiry, and solving real-world problems** as key methodologies in competency development. Through trilingual digital platforms, students perform tasks independently, which contributes to the **practical formation of theoretical knowledge**.

Lev Vygotsky (Russia) — advocate of the **interrelation between language and thinking.** According to Vygotsky, **language is a carrier of thought**. He

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substantiates the necessity of using language as a tool for forming concepts and developing thinking during the learning process.

The **trilingual methodology** is based precisely on this principle: expressing a single mathematical concept in different languages enhances **semantic analysis** and **cognitive flexibility** in learners.

John Sweller (Australia) — Author of the **Cognitive Load Theory** According to Sweller's Cognitive Load Theory, breaking down learning material into manageable parts and presenting it with visual aids facilitates **easier comprehension** and **better retention**. Trilingual educational tools such as **GeoGebra** and **Desmos** are built upon this very approach — they present each mathematical formula in a **visual format**, making it more accessible and cognitively manageable for students.

John Hattie (New Zealand) — Researcher emphasizing the importance of **students' metacognitive development.** Hattie asserts that for deep learning to occur, students must not only acquire knowledge but also become aware of **how they learn**, reflect on their own thinking processes, and regulate their strategies accordingly. Trilingual platforms support this by encouraging students to engage with mathematical content **critically, reflectively, and across multiple linguistic and representational modes**.

In his synthesis of over 800 meta-analyses, *John Hattie* emphasizes in his book *"Visible Learning"* that **metacognition** — the learner's ability to observe and regulate their own thinking process — has the most significant impact on learning outcomes.

Through trilingual educational software, students are able to **identify their own mistakes**, **edit graphs**, and **analyze formulas in real time**, which actively cultivates their **metacognitive skills** and enhances self-regulated learning.

S.K. Yunuskhodjayeva (Uzbekistan) — Local theoretical approach Yunuskhodjayeva, in her research, advocates for the application of **cognitive approaches** in mathematics education, emphasizing the importance of engaging students as **active participants** in the learning process and fostering **independent thinking**.

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This aligns with trilingual environments, where interactive tools **stimulate active classroom participation** and help learners build cognitive and reflective competencies through **multilingual engagement**.

Cognitive competence is not merely a collection of knowledge, but rather the ability to **apply knowledge in practice**, **solve problems**, and demonstrate **critical and creative thinking** (Sun & Hui, 2006). Therefore, the assessment of this competence cannot be limited to traditional testing methods. Instead, it requires a more **performance-based**, **activity-oriented approach**.

As **Zimnyaya (2003)** emphasizes, assessing competencies should be based on how they **manifest in functional contexts**: that is, how the student thinks, what solutions they develop, what choices they make, and how well they can justify those decisions.

Furthermore, the **competency-based lesson design model** proposed by **Nazarova F. (2020)** is adaptable to **trilingual education**, as it is aimed at ensuring the integration of **language and logical reasoning** within the learning process.

D.R. Ergashova recommends methods for developing **cognitive competence** through the integration of **modern digital technologies**.

Jim Cummins' foundational theory on **multilingual education** introduces the concept of **cross-linguistic transfer**, which suggests that knowledge acquired in one language can be transferred to another. According to Cummins, language is not only a means of communication, but also a **critical tool for cognitive development**.

He distinguishes between two types of language proficiency:

- **BICS** – Basic Interpersonal Communicative Skills (everyday conversation).
- **CALP** – Cognitive Academic Language Proficiency (academic language required for learning complex concepts).

In the context of education, applying Cummins' theory through **trilingual software** allows students to develop CALP in **all three languages**, thereby enhancing their **cognitive competence** and **cross-disciplinary language capacity**.

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According to **Cummins (2000)**, students' **personal and cognitive development** is closely connected to their **native language, cultural identity, and social environment**. When schools maintain a **positive attitude** toward the student's mother tongue and cultural background, it increases **academic engagement** and strengthens **knowledge retention**.

Thus, there is a strong theoretical foundation for developing students' **cognitive competencies** through the use of **trilingual educational software** in mathematics classrooms. Trilingual platforms not only support language development but also foster **deep thinking**, **analytical skills**, **problem-solving abilities**, and **logical reasoning**, all of which are essential aspects of cognitive activity.

According to **Richard E. Mayer's Multimedia Learning Theory**, the human brain processes information through **two separate channels**: **visual** and **auditory**. The effectiveness of learning depends on the **synchronization of text, images, sound, and animation**.

To reduce **cognitive load**, Mayer recommends the use of **segmentation**, **engaging contexts**, and **adaptive visual elements**.

Educational implications:

In **trilingual educational software**, the integration of multimedia components—such as **video lessons, interactive graphics, and audio-based tasks**—facilitates **deeper knowledge acquisition**. This is especially beneficial for enhancing **cognitive competence** in subjects like **mathematics and language learning**, where abstract and linguistic content often intersects.

The term **metacognition** was first scientifically introduced by **John H. Flavell**, who defined it as:

"Metacognition refers to one's ability to reflect on, understand, and regulate their own thinking, knowledge, and learning strategies."

This ability to **monitor and control cognitive processes** is critical in fostering **independent learning**, **problem-solving**, and **higher-order thinking**, all of which are key elements of **cognitive competence** in trilingual learning environments.

Flavell divides **metacognition** into the following components:

1. **Metacognitive Knowledge** – awareness and understanding of one's own learning processes.

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2. **Metacognitive Monitoring** – the ability to observe and reflect on one's learning during the learning process.
3. **Metacognitive Control** – the ability to select and apply appropriate learning strategies when necessary.

According to **Flavell (1979)**, metacognition refers to the individual's knowledge about their own cognitive processes and the ability to actively monitor and regulate those processes. Metacognitive activity supports learners in self-evaluation, selecting appropriate strategies, and organizing their learning purposefully.

Based on **Flavell's (1979) theory**, students learn to consciously manage their thinking and learning processes, which in turn strengthens their **cognitive competence**.

Furthermore, **Mayer (2001)** emphasizes in his **multimedia learning model** that effective learning is largely dependent on the learner's active engagement. The learner must be able to **select relevant information**, **organize it coherently**, and **integrate it with existing knowledge**. This process is one of the key indicators of **cognitive competence**.

The theoretical perspectives of the aforementioned scholars demonstrate that the use of **trilingual software tools** in mathematics lessons not only enhances **language competence**, but also has a significant impact on the development of **deep cognitive thinking**, **problem analysis**, and **metacognitive activity**. This provides a solid scientific foundation for the theoretical framework of the present article.

In mathematics classes, students often need to study a topic independently, or teachers seek additional resources in other languages to provide broader explanations. For example, take the topic "**Regular polyhedra**" in geometry. A teacher explains that regular polyhedra include the **hexahedron (cube)**, **tetrahedron**, **octahedron**, **dodecahedron**, and **icosahedron**. The definitions of these shapes, as well as the number of their **vertices, faces**, and **edges**, are given. In the case of the **hexahedron (cube)**, the teacher introduces its **elements of symmetry**, including **center of symmetry**, **axes of symmetry**, and **planes of symmetry**. Detailed information is provided on how many symmetry elements

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the cube possesses, what constitutes the center of symmetry, which edges form the axis of symmetry, and which planes correspond to symmetry planes.

However, if the teacher does not have sufficient information about the symmetry elements of the other regular polyhedra, they may refer to **educational resources in other languages** (such as Russian or English), including **video lessons**, **online articles**, and **scientific references**. In such cases, **trilingual educational software** plays a vital role in supporting the teaching and learning process.

Indeed, I have encountered such situations in practice. As a result, I expanded my **database of regular polyhedra** with the following additional information:

The **tetrahedron** has *no center of symmetry*. Its **axes of symmetry** are the segments connecting the midpoints of opposite edges, of which there are **three**. A **plane of symmetry** passes through one edge and is perpendicular to the opposite edge, yielding a total of **six planes of symmetry**.

The **octahedron** possesses **one center of symmetry**. Its **axes of symmetry** are straight lines that pass through pairs of opposite vertices and the midpoints of opposite edges, making a total of **nine axes**. The **planes of symmetry** include:

- **Three** planes: two vertical and one horizontal, each passing through four vertices.
- **Six** additional planes: each passes through two non-adjacent vertices and opposite edges.

This results in a total of **nine planes of symmetry**.

The **dodecahedron** has **one center of symmetry**. Its **axes of symmetry** are straight lines connecting the midpoints of opposite edges, totaling **fifteen**. The **planes of symmetry** pass through a vertex of one face and the midpoint of the edge opposite to it, also totaling **fifteen planes**.

The **icosahedron** also has **one center of symmetry**. Its **axes of symmetry** are straight lines that pass through the midpoints of opposite, parallel edges, of which there are **fifteen**. Each **plane of symmetry** passes through four vertices lying in the same plane and the midpoint of the edge opposite to them. There are **fifteen such planes**.

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Based on this classroom experiment, the following scientific hypotheses are proposed:

- If mathematics lessons are conducted using **trilingual educational software**, students will demonstrate a significant improvement in **cognitive competence**.
- If mathematical topics are explained using not only Uzbek-language resources but also comprehensive materials in **Russian and English**, students' comprehension, **critical thinking**, and **creative reasoning skills** will increase by **40–50%**.
- If a **trilingual methodology enriched with interactive technologies** is applied, students' **motivation toward mathematics** and their ability for **self-monitoring** will significantly improve.

The **trilingual methodological approach** is a crucial factor in raising the **quality of mathematics education** to a new level. The diversification of languages plays an essential role in developing students' **cognitive competencies**, enabling them to **think deeply**, **analyze**, **compare**, and **make independent decisions**. Therefore, implementing this methodology gradually in mathematics instruction is deemed highly effective.

These methods:

- **Deeply enhance cognitive competence**;
- Compel students to think **logically, independently, and creatively**;
- **Integrate the trilingual approach** into active thinking processes, thereby stimulating **multichannel cognitive activity**.

In mathematics education, **trilingual software** can serve as an effective tool for fostering students' **cognitive competencies**. This methodology not only facilitates **interdisciplinary and multilingual integration**, but also promotes students' **intellectual independence**.

In the future, it will be essential to develop **advanced, specialized curricula** in this domain, along with comprehensive **assessment mechanisms** for evaluating cognitive and linguistic outcomes.

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