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# Робота з даними як засіб формування логічного складника математичної компетентності учнів основної школи: огляд американського досвіду

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**Анотація.** Стаття присвячена проблемі розширення методичного інструментарію формування логічного складника математичної компетентності учнів основної школи засобами роботи з даними. Обґрунтовано, що статистичне мислення є не відокремленою навчальною лінією, а виявом тих самих логічних операцій – аналізу, синтезу, порівняння, класифікації, узагальнення, доведення та обґрунтування, – які утворюють когнітивне ядро логічного складника математичної компетентності. Грамотність у роботі з даними є ключовою вимогою сучасного ринку праці, що надає навчанню цих операцій безпосереднього мотиваційного горизонту для учнів. На основі аналізу американського досвіду – керівництва для оцінювання та навчання зі статистичної освіти GAISE, стандартів CCSS (Common Core State Standards), досліджень Wild і Pfannkuch, Garfield і Ben-Zvi – показано, що дані є унікально продуктивним середовищем для формування всіх чотирьох компонентів логічного складника (мотиваційно-ціннісної, когнітивної, діяльнісної, рефлексивно-оцінної). Розроблено таблицю відповідності логічних операцій вимірам статистичного мислення та показникам сформованості логічного складника, яка узгоджує американські підходи з чотирикомпонентною структурою логічного складника, обґрунтованою в попередніх дослідженнях автора. Запропоновано систему з п'яти контекстних завдань для учнів, що моделюють реальні життєві ситуації – роботу із соціологічними, ціновими, ігровими та антропометричними даними – і орієнтовані на різні логічні операції: порівняння, класифікацію, синтез, доведення. Сформульовано методичні рекомендації для вчителів математики основної школи.

**Ключові слова:** аналіз даних, грамотність у роботі з даними, компетентнісний підхід, логічний складник математичної компетентності, методика навчання математики, основна школа, статистичне мислення, система задач.

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# Data-Based Work and the Logical Component of Mathematical Competence: The American Experience

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**Abstract.** This article addresses the problem of expanding the methodological toolkit for forming the logical component of basic school students' mathematical competence through data-based work. It is substantiated that statistical thinking is not a separate strand of instruction but a manifestation of the same logical operations – analysis, synthesis, comparison, classification, generalization, proof, and justification – that form the cognitive core of the logical component of mathematical competence. Data literacy is a key requirement of the modern labor market, which gives the teaching of these operations a direct motivational horizon for students. Based on an analysis of American experience – the Guidelines for Assessment and Instruction in Statistics Education (GAISE), the Common Core State Standards (CCSS), and the research of Wild and Pfannkuch, Garfield and Ben-Zvi – it is shown that data constitute a uniquely productive environment for forming all four components of the logical component (motivational-value, cognitive, activity-based, and reflective-evaluative). A correspondence table linking logical operations, dimensions of statistical thinking, and indicators of the logical component was developed, aligning American approaches with the author's own four-component framework. A system of five contextual tasks is proposed, modeling real situations – sociological, price, game-based, and anthropometric data – and targeting different logical operations: comparison, classification, synthesis, and proof. Methodological recommendations for basic school mathematics teachers are formulated.

**Keywords:** data analysis, data literacy, competence-based approach, logical component of mathematical competence, methodology of teaching mathematics, basic school, statistical thinking, system of tasks.

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**Problem Statement.** The ability to think critically and make data-driven decisions has become not only an educational goal but also a key requirement of the modern labor market. In the fields of data analytics, marketing, healthcare, and public administration, professionals are expected to be able to investigate, analyze, and generalize data and justify conclusions – that is, to perform precisely those logical operations whose development is the goal of teaching mathematics in basic school. This means that forming the logical component of mathematical competence through data-based work not only aligns with the goals of Ukrainian schooling but also directly prepares students for genuine participation in today's information society.

We have substantiated the logical component of basic school students' mathematical competence in our previous research (Milian, 2021) as a dynamic combination of abilities that unites understanding of the logic of events, logical skills, and experience in using them, necessary for carrying out mathematical and/or personally meaningful productive activity. The structure of the logical component is formed by the unity of the motivational-value, cognitive, activity-based, and reflective-evaluative components. A specialized system of tasks has been identified as the main means of forming it (Milian, 2021). At the same time, the potential of data and statistics as an environment for developing the logical component of mathematical competence requires further methodological reflection. In this context, approaches presented in the American scientific-methodological literature are of interest, where working with data and statistics is considered an important resource for developing students' logical and mathematical thinking. An analysis of these approaches is presented in this article.

**Analysis of Sources and Recent Research.** The problem of forming students' mathematical competence has been studied by many Ukrainian scholars, including M. S. Holovan, O. I. Matiash, S. A. Rakov, S. O. Skvortsova, N. A. Tarasenkova, and others. An analysis of foreign research on forming students' logical competence was carried out in our earlier work (Milian, 2020). Notably, research in this direction is actively continuing: a recent study by O. Matiash and I. Velbitskaya conducted a comparative analysis of American technologies for developing primary school students' logical-mathematical thinking, demonstrating continuity of approaches to developing logical thinking between primary and basic school (Matiash & Velbitskaya, 2025). Within this article, we focus on approaches to developing statistical thinking presented in the works of American researchers C. Wild and M. Pfannkuch, J. Garfield and D. Ben-Zvi, C. Franklin et al., and C. Langrall et al., examining them through the lens of the logical component of students' mathematical competence.

**Key Approaches of the American Scientific-Methodological Tradition.** The Guidelines for Assessment and Instruction in Statistics Education (GAISE) (Franklin et al., 2007; updated by Bargagliotti et al., 2020) is the most influential American document for teaching statistics in K–12. It describes three levels of development (A, B, C), of which levels A and B correspond approximately to grades 5–8. At level B, students are expected to: design data collection with awareness of potential sources of bias; move from displaying individual values to distributional thinking; formulate informal conclusions from samples; and make an initial assessment of the relationship between two variables. These expectations directly correspond to the indicators of the activity-based and reflective-evaluative criteria for the formation of the logical component (Milian, 2021). It is worth noting that GAISE's four-stage model (formulate a question – collect data – analyze data – interpret results) echoes the earlier and more detailed model of the PPDAC investigative cycle (Problem – Plan – Data – Analysis – Conclusion), proposed by Wild and Pfannkuch, underscoring the continuity and coherence of the American tradition of statistics education (Wild & Pfannkuch, 1999).

The Common Core State Standards (CCSS, 2010) incorporate work with data and statistics into the grades 6–8 curriculum, building a clear progression: in grade 6, students master statistical questions and measures of central tendency and spread; in grade 7, random sampling and comparative statistics; and in grade 8, bivariate data and linear association. In doing so, the standards place emphasis not on computation but on reasoning about data: students are required to interpret, compare, and evaluate – that is, to perform precisely the logical operations that form the core of the logical component of mathematical competence (Milian, 2021).

Garfield and Ben-Zvi found that students demonstrate the greatest progress in statistical thinking under the following conditions: tasks use real, contextually meaningful data; students formulate their own questions for analysis; instruction explicitly reveals the distinction between statistical and mathematical thinking; and students are engaged in joint reasoning and argumentation (Garfield, 2008). The principles formulated by these researchers closely echo the organizational-pedagogical conditions for the effective formation of the logical component of students' mathematical competence that we substantiate in our own work (Milian, 2021).

**Identification of Previously Unresolved Parts of the General Problem.** Despite the thoroughness of the approaches examined, the sources analyzed leave unaddressed the question of practically implementing statistical thinking through a concrete system of tasks aimed at forming the logical component of basic school students' mathematical competence. American sources (GAISE, CCSS, the research of Wild and Pfannkuch, Garfield and Ben-Zvi) reveal the theoretical dimensions of statistical thinking but do not offer methodological developments adapted to the domestic educational context or aligned with the four-component structure of the logical component of mathematical competence substantiated in our previous research. This necessitates developing a corresponding system of tasks for basic school.

**Aim of the Article** – based on an analysis of American experience in teaching statistical thinking and data literacy, to substantiate the potential of data-based work as a means of forming the logical component of basic school students' mathematical competence and to propose a corresponding system of tasks.

**Presentation of the Main Material.**

**Statistical Thinking as a Manifestation of Logical Operations in Working with Data.**

In our previous research (Milian, 2021), we specified indicators of the formation of the logical component of students' mathematical competence according to four criteria. In particular, within the activity-based criterion, the following analytical skills are identified: analyzing data and relationships between them; selecting the data needed for a solution; formulating assumptions and investigating their validity. The reflective-evaluative criterion includes the ability to critically evaluate the process and outcome of a solution, draw conclusions based on the results obtained, present results, and provide arguments. These indicators are, in essence, a description of what the American scientific-methodological literature calls statistical thinking.

Wild and Pfannkuch, within their model of "types of thinking" – one of several components of their broader concept of statistical thinking – define statistical thinking through five types: recognition of the need for data, transnumeration (changing data representations to reveal new meaning), consideration of variation, reasoning with statistical models, and integration of the statistical and the contextual (Wild, Pfannkuch, 1999). Garfield and Ben-Zvi emphasize that statistical thinking is not computational but explanatory and evaluative in nature (Garfield, Ben-Zvi, 2008). The GAISE guidelines define statistical thinking as a four-stage investigative process: formulate a statistical question, collect data, analyze data, interpret results. GAISE's distinction between statistical questions (which anticipate variability in the answer) and mathematical questions (which have a single correct answer) is fundamentally important: it helps students understand that reasoning with data is connected to uncertainty and inference, not merely to computation.

Comparing these approaches with the four-component structure of the logical component of mathematical competence (Milian, 2021) reveals a deep substantive correspondence. Table 1 reflects this connection, linking each logical operation to the corresponding dimension of statistical thinking and a specific indicator of the formation of the logical component.

**Table 1. Correspondence Between Logical Operations, Statistical Thinking Dimensions, and Logical Component Indicators**

| Logical Operation | Dimension of Statistical Thinking | Indicator of the Formation of the Logical Component |
|---|---|---|
| Analysis | Decomposing a dataset into variables, identifying relationships | Analyzing data and relationships between them (activity-based criterion) |
| Synthesis | Transnumeration: combining data into a new holistic representation | Identifying and describing mathematical characteristics, relationships between objects (activity-based criterion) |

| | | |
|---|---|---|
| Comparison | Comparing distributions, groups, trends | Classifying mathematical objects by shared features, recognizing analogies (activity-based criterion) |
| Classification | Distinguishing data types, categorization | Ways of recording and representing mathematical information in various forms (cognitive criterion) |
| Generalization | Drawing conclusions beyond the sample, identifying patterns | Formulating assumptions and investigating their validity; predicting outcomes (activity-based criterion) |
| Proof / Justification | Critically evaluating claims based on data, identifying limitations | Critically evaluating the process and result; drawing conclusions; formulating counterarguments (reflective-evaluative criterion) |

The comparison presented allows us to assert that working with data is not a separate strand of instruction but a manifestation of the same logical operations within a subject domain that holds heightened motivational value for basic school students. A student who finds it difficult to engage with abstract algebraic generalization can become fully engaged in the very same operations while working with real data about sports, weather, prices, or the environment. This directly strengthens the motivational-value component of the logical component. It is also important that the logical operations involved in working with data coincide with those performed by data analysts, marketers, and researchers in their everyday work, which gives instruction a practical horizon that is meaningful to students.

**System of Tasks for Forming the Logical Component through Data-Based Work.**

A specialized system of tasks is the main means of forming the logical component of basic school students' mathematical competence (Bachynska, 2018; Matiash et al., 2022). Applying this principle to the domain of data-based work, we present five model tasks that correspond to the active-practical and exploratory-creative stages of our staged methodology. Each task is formulated as an open-ended investigation and linked to specific indicators of the formation of the logical component.

*Task 1. What Does Our Class Like?*

*Target operations:* comparison, generalization. Components: activity-based, reflective-evaluative. Time: 45 min.

*Data source:* a survey conducted in class the day before the lesson – each student records how many hours per week they spend on three types of leisure activities: reading books, playing sports, and social media/phone games, etc. The data is compiled into a combined class table (separately for boys and girls).

*Procedure:* 1. Examine the compiled class data table. What do you notice when comparing boys and girls? 2. Calculate the average number of hours per week for each leisure activity, separately for boys and for girls. 3. Build a bar chart comparing the average figures for boys and girls across the three leisure activities. 4. The school council wants to introduce one new club for the class (a sports club, a book club, or a media club). Based only on this data, which club would you recommend? Write 3–4 sentences with justification. 5. What additional data would you need for a final recommendation? (For example: do students actually want a club, or are they simply spending time this way due to a lack of alternatives? Is the interest the same for everyone?)

*Methodological commentary:* Question 3 forms the operation of comparison through visual representation (cognitive and activity-based criteria). Question 4 requires generalization and justification – indicators of the reflective-evaluative criterion. Question 5 develops the ability to identify the limitations of data – a skill that naturally emerges here through the difference between what behavioral data shows and what students actually want.

*Task 2. Is This Headline True?*

*Target operations:* analysis, proof, and justification. Components: activity-based, reflective-evaluative. Time: 45 min.

*Headline:* Teen screen time has risen 40% since 2021 – experts warn of a learning crisis.

*Data:* average daily screen time (hours) for students aged 13–15: 2021 – 3.2; 2022 – 5.1; 2023 – 5.4; 2024 – 5.6; 2025 – 5.8.

*Procedure:* 1. Calculate the percentage change in screen time from 2021 to 2025. Does the result match the claim of “40%”? 2. Calculate the percentage change from 2021 to 2024. What number do you get? 3. Which year did the journalist choose as the starting point? Is this choice justified? 4. Build a line graph of the data. Does it create the same impression as the headline? 5. Write an evaluative response to the headline: is it accurate, misleading, or somewhere in between? Justify your answer with specific numbers.

*Methodological commentary:* This task develops the most cognitively demanding indicator of the reflective-evaluative criterion – the ability to constructively respond to arguments and formulate counterarguments. It introduces the concept of baseline manipulation – a key data-analysis skill needed both for critical media literacy and for any analytical work with statistics.

*Task 3. Are Height and Math Performance Related?*

*Target operations:* classification, synthesis, generalization. Components: all four. Time: 2 lessons.

*Data:* collected in class – students measure their own height and record their score from the most recent math test (or the teacher provides a simulated dataset).

*Procedure:* Lesson 1: 1. Before looking at the data, write down your prediction and reasoning: is there a relationship between height and math performance? 2. Classify students into three groups by height (define the boundaries and justify your choice). Calculate the average score for each group.

3. Build a scatter plot: height (X-axis) and score (Y-axis). Describe what you see. Lesson 2: 4. Does the plot indicate a relationship? How strong is it, and in which direction? 5. A classmate claims: "The data proves that taller students are better at math." Evaluate this claim. 6. What is a hidden (confounding) variable? Name one that could explain the relationship found. (Hint: age – older students are both taller and have more experience studying math.)

*Methodological commentary:* This task develops classification (grouping by height), synthesis (a scatter plot as a combination of two variables), and generalization (drawing a conclusion from the graph). Question 1 activates the motivational-value component through prediction. Questions 5–6 introduce the concepts of correlation and confounding variables – critically important logical-thinking skills that correspond to the reflective-evaluative component and are foundational for data-analysis practice.

*Task 4. Where Is It Cheaper to Buy Groceries?*

*Data source:* at home (with parents' help), students record the prices of 6–8 identical products (bread, milk, eggs, bananas, etc.) at two different stores near their home. The data is compiled into a combined class table.

*Procedure:* 1. Examine the compiled price table. What do you notice? 2. Classify the products into two groups: "cheaper at Store A" and "cheaper at Store B." Which group has more products? 3. Calculate how much the same basket of these products would cost at each store. 4. A family wants to save money by buying everything at one store. Which store would you recommend? Are there products worth buying at the other store, even if it is less advantageous overall? 5. What else, besides price, affects the choice of store (distance, quality, hours of operation)?

*Methodological commentary:* This task introduces students to working with real data through a simple, accessible everyday situation. Question 2 forms the operation of classification (cognitive criterion); question 4 develops early analytical skills that account for exceptions, preparing students for the more complex operations of comparison and generalization in the subsequent tasks of the system.

*Task 5. What Will You Roll?*

*Data source:* an in-class experiment – each student rolls two dice 20 times and records the sum of the numbers rolled after each roll. The results of the whole class are compiled into one combined table.

*Procedure:* 1. Count how many times each sum from 2 to 12 occurred (using the whole class's data). 2. Build a bar chart: the X-axis shows the sum (2–12), and the Y-axis shows how many times it occurred. 3. Which sum occurs most often? Count how many different ways a sum of 7 can be obtained from two dice (for example, 1+6, 2+5, 3+4...), and how many ways a sum of 2 can be obtained. Does this explain the shape of the chart? 4. If each student had rolled the dice only 2 times instead of 20, would the distribution look the same? What happens to the shape of the chart if you combine the data with that of another class? 5. One student says: “The dice are unfair, because a sum of 7 came up most often.” Do you agree with this claim? Justify your answer.

*Methodological commentary:* This task illustrates consideration of variation – one of the five types of statistical thinking identified by Wild and Pfannkuch at the beginning of the article, but not yet embodied in any of the previous tasks. Question 3 develops analysis by combining experimental data with combinatorial reasoning (cognitive criterion). Question 4 builds an understanding of how sample size affects the stability of a distribution – a fundamental idea in statistical thinking. Question 5 reinforces the highest-level reflective-evaluative indicator: the ability to distinguish random deviation from systematic error based on the data itself.

Summarizing the experience examined, we formulate several practical guidelines for teachers.

1. Formulate data-based tasks as open-ended investigations rather than closed exercises. The most consistent finding of American research (Garfield & Ben-Zvi, 2008; Langrall et al., 2017) is that statistical thinking and the associated logical operations develop through genuine investigation rather than through applying formulas to artificial datasets. Each task should begin with a meaningful question, be built on real or realistic data, and end with a conclusion requiring justification. The five tasks presented are models corresponding to the active-practical and exploratory-creative stages of the staged methodology for forming the logical component of mathematical competence (Milian, 2021).

2. Explicitly name the logical operations at each stage of working with data. When students sort data by category, the teacher names this action classification. When they draw a conclusion from a graph, the teacher reminds them that this is a generalization and that it requires justification. This kind of metacognitive scaffolding helps students transfer logical-thinking skills from data-based contexts to other areas of mathematics.

3. Use real, open data. Using authentic data creates a genuine context and directly strengthens the motivational-value component of the logical component of mathematical competence.

4. Develop critical evaluation of data-based claims as a distinct methodological priority. Task 2 illustrates an approach that deserves systematic implementation: teaching students to identify and evaluate manipulative techniques in statistical reporting. In an information environment saturated with data-backed claims, the ability to ask “Does this data actually support this claim?” is one of the most practically significant outcomes of mathematics education. This directly develops the reflective-evaluative criterion for the formation of the logical component.

5. Connect data-based work to students' future professional activity. Teachers should explain to students that the logical operations they carry out in data-based tasks – analysis, comparison, generalization, critical justification – are the very same operations performed by data analysts, marketers, researchers, and civil servants in their daily work. This gives students a motivational horizon beyond the classroom and establishes a connection between school mathematics and future educational and professional trajectories.

**Conclusions.** This article substantiates the organic connection between statistical thinking and the logical component of basic school students' mathematical competence. It is shown that working with data is not a separate strand of instruction but a manifestation of the same logical operations within a subject domain distinguished by heightened motivational value for students and a direct connection to the demands of the modern labor market.

An analysis of American experience (the Guidelines for Assessment and Instruction in Statistics Education (GAISE), the Common Core State Standards, and the research of Wild and Pfannkuch, Garfield and Ben-Zvi) confirmed the methodological conclusions of our own research: the most effective means of developing logical thinking is open-ended investigative tasks using real data that require students to perform every operation from formulating a question to critically evaluating a conclusion. Five model tasks have been proposed, linked to specific indicators of the formation of the logical component across four criteria, and methodological recommendations have been formulated.

***Conflict of Interest.*** *The author declares no conflict of interest regarding this study, including of a financial, personal, authorship-related, or any other nature that could have influenced the course of the research and its results as presented in this article.*

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