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A linguistic and didactic resource in the formation of mathematical competence of secondary school students when studying the syntax of the Ukrainian language (on the material of syntactic derivatives)

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Abstract. This study explores the development of mathematical competence in secondary school students through the study of Ukrainian language syntax, focusing on syntactic derivatives. The theoretical framework integrates competence, activity, functional-stylistic, and cognitive approaches to studying syntax. Constructional and compositional analyses were used to examine types of algebraic phrases, sentences, and word problems. Results indicate that understanding syntactic features and derivational processes can enhance students' mathematical skills, problem-solving abilities, and communication. Pedagogical implications include using authentic tasks, encouraging verbalization of thinking, and providing linguistic support. This research highlights the interdependence of language and mathematical learning, offering strategies to improve conceptual understanding and performance in mathematics education.

Keywords: mathematical competence, Ukrainian language, syntactic derivatives, secondary education, language and mathematics interrelation, algebraic language, word problems, pedagogical strategies

1. Introduction

The formation of mathematical competence in secondary school students is closely tied to their linguistic skills, particularly in understanding and utilizing the specialized syntax of mathematical language [2, 11]. As Bautista, Mulligan and Mitchelmore [3] notes, the semantics of the language, including restating, deriving, inferring, comparing, and contrasting, are essential for grasping mathematical concepts. Algebraic expressions and operations can be more effectively learned by focusing on word cues, syntactic structures, and the meaning of mathematical problems [4, 6].

Recent research has delved deeper into the nexus between language proficiency and mathematics achievement. Longitudinal studies by Paetsch and Kempert [13] found that grammatical skills, especially in the early years, significantly impact later mathematical learning. Vocabulary knowledge and reading comprehension have also been consistently linked to performance on tasks like word problems [17, 18]. However, the relative contribution of specific linguistic components to different mathematical competencies remains an area for further investigation [8, 14].

This study *aims* to elucidate the role of Ukrainian syntax, particularly syntactic derivatives, in fostering secondary students' mathematical competence.

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2. Theoretical background

The development of mathematical competence through language study is grounded in several interconnected theoretical perspectives. The competence approach emphasizes the application of knowledge and skills to solve problems in various contexts [9]. In mathematics education, this translates to the ability to use mathematical concepts, procedures, and reasoning to interpret, formulate, and solve problems across a range of situations [12]. Language competencies, including the understanding and use of specialized vocabulary, syntax, and discourse structures, are seen as integral to mathematical literacy [16].

The activity approach focuses on the role of goal-directed actions in learning and development [10]. In the context of mathematics education, this involves engaging students in authentic problem-solving tasks that require the application of mathematical knowledge and skills. Language serves as a tool for mediating these activities, both in terms of internal cognitive processes and external communication with others [19]. Verbalizing mathematical thinking, explaining solution strategies, and participating in mathematical discussions are all linguistic activities that support the construction of mathematical understanding.

The functional-stylistic approach draws attention to the ways in which language varies according to its purpose and context of use [7]. Mathematical language has its distinct features, such as specialized vocabulary, symbolic notation, and concise grammatical structures [15]. These features reflect the abstract, logically structured nature of mathematical knowledge. Mastering the functional style of mathematical language involves understanding how its linguistic elements work together to convey precise meanings and support logical reasoning.

The cognitive approach investigates the mental processes involved in learning and using language and mathematics [1]. This includes the acquisition and organization of conceptual knowledge, the development of problem-solving strategies, and the role of metacognition in monitoring and regulating one's thinking. Research has shown that language and mathematical cognition are closely intertwined, with language serving as a representational system for mathematical concepts and a means of processing mathematical information [5].

Integrating these theoretical perspectives provides a comprehensive framework for examining the linguistic and didactic resources involved in the formation of mathematical competence. The study of syntactic derivatives, in particular, offers a window into the structural relationships and transformational processes that underlie mathematical language and thought.

3. Methodology

3.1. Research design

This qualitative study employed a descriptive-analytical design to investigate the role of Ukrainian syntactic derivatives in the formation of mathematical competence among secondary school students. The research involved three main phases: (1) content analysis of curricular materials and linguistic resources related to the study of Ukrainian syntax and mathematical problem solving; (2) constructional and compositional analysis of authentic algebraic expressions, sentences, and word problems; and (3) synthesis of findings and pedagogical implications.

3.2. Data collection

The primary data sources for this study included:

1. Ukrainian language arts and mathematics curriculum standards for grades 5-9, which outline the expected learning outcomes and core content related to language and mathematical competencies.
2. Textbooks and instructional materials used in Ukrainian language arts and mathematics courses, which provide examples of syntactic structures, algebraic expressions, and problem-solving tasks.

3. Samples of student work, including written solutions to mathematical problems and linguistic exercises, which demonstrate the application of syntactic knowledge in mathematical contexts.

These data sources were selected to capture the range of linguistic and mathematical content that secondary school students encounter in their formal education and their actual performance on relevant tasks.

3.3. Data analysis

The content analysis phase involved a systematic review of the collected curricular materials and linguistic resources to identify key concepts, skills, and instructional strategies related to the study of Ukrainian syntax and its potential applications in mathematical problem-solving. This analysis focused on identifying the types of syntactic structures and transformations emphasized in the language arts curriculum and the mathematical concepts and problem-solving strategies highlighted in the mathematics curriculum.

The constructional and compositional analysis phase involved a detailed examination of authentic algebraic expressions, sentences, and word problems drawn from textbooks and student work samples. This analysis aimed to uncover the underlying structural patterns and derivational relationships among these linguistic elements, as well as their semantic and pragmatic functions in mathematical contexts. Specific attention was paid to the role of syntactic derivatives, such as nominalization, verbalization, and adverbialization, in the formation and transformation of mathematical expressions.

The synthesis phase involved integrating the findings from the content and linguistic analyses to identify key insights and pedagogical implications for the development of mathematical competence through the study of Ukrainian syntax. This synthesis considered the theoretical perspectives outlined in the previous section, as well as the empirical evidence gathered through the analysis of authentic linguistic and mathematical data.

4. Results and discussion

4.1. Syntactic derivatives in mathematical expressions

The analysis of algebraic expressions in Ukrainian revealed a high frequency of syntactic derivatives, particularly in the form of nominalizations and verbalizations. Nominalizations, which transform verbs or adjectives into nouns, were commonly used to represent mathematical operations and quantities. For example, the expression "різниця двох чисел" (lit. "difference of two numbers") nominalizes the verb "відрізняти" (lit. "to subtract") to refer to the result of a subtraction operation. Similarly, the expression "добуток трьох множників" (lit. "product of three factors") nominalizes the verb "множити" (lit. "to multiply") to represent the result of a multiplication operation.

Verbalizations, which transform nouns or adjectives into verbs, were also prevalent in algebraic expressions. These verbalizations often signalled the application of a mathematical operation or relationship to a set of quantities. For instance, the expression "розділити на три рівні частини" (lit. "to divide into three equal parts") verbalizes the noun "частина" (lit. "part") to indicate the act of division. Similarly, the expression "збільшити на п'ять одиниць" (lit. "to increase by five units") verbalizes the adjective "більший" (lit. "greater") to represent the operation of addition.

The use of syntactic derivatives in algebraic expressions serves several important functions. First, it allows for the concise and precise representation of mathematical concepts and operations, which is essential for effective problem-solving and communication. Second, it highlights the structural relationships among different elements of an expression, such as the inputs and outputs of a particular operation. Third, it facilitates the transformation and manipulation of expressions, as nominalizations and verbalizations can be easily rearranged or substituted to derive new forms or solve for unknown quantities.

4.2. Syntactic derivatives in algebraic sentences and word problems

Algebraic sentences and word problems in Ukrainian also exhibited a high degree of syntactic derivation, particularly in the form of complex noun phrases and subordinate clauses. These structures often served to condense and organize the information needed to set up and solve a mathematical problem.

For example, consider the following word problem:

> *Григорій Сковорода, український письменник епохи бароко, є автором філософської притчі «Бджола та Шершень», у якій розкрито сутність «сродної праці» // Український письменник епохи бароко Григорій Сковорода є автором філософської притчі «Бджола та Шершень», у якій розкрито сутність «сродної праці».*
>
> Hryhorii Skovoroda, a Ukrainian writer of the Baroque era, is the author of the philosophical parable "The Bee and the Hornet", which reveals the essence of "congenial work" // The Ukrainian writer of the Baroque era Hryhorii Skovoroda is the author of the philosophical parable "The Bee and the Hornet", which reveals the essence of "congenial work".

In this problem, the complex noun phrase "Григорій Сковорода, український письменник епохи бароко" (lit. "Hryhorii Skovoroda, a Ukrainian writer of the Baroque era") serves to identify the subject of the sentence and provide background information relevant to the problem context. The subordinate clause "у якій розкрито сутність «сродної праці»" (lit. "in which the essence of 'congenial work' is revealed") further specifies the content and significance of the parable mentioned in the main clause.

Information condensation through syntactic derivatives allows for a more efficient representation of the problem situation and a clearer delineation of the relevant variables and relationships. This can help students identify the key elements of the problem and develop a strategic approach to solving it.

Furthermore, by incorporating engaging and real-world circumstances, the use of syntactic derivatives in word problems can further motivate students by stimulating their curiosity and practical expertise. Teachers can encourage students to use their language skills to support mathematics knowledge and problem-solving by presenting mathematical issues as stories or scenarios that incorporate intricate linguistic elements.

4.3. Authentic examples and tasks

To illustrate the role of syntactic derivatives in mathematical problem solving, we present a series of authentic examples and tasks drawn from Ukrainian language arts and mathematics curricular materials for grades 5-9. These examples showcase the various types of nominalizations, verbalizations, and clause structures that students encounter in algebraic expressions, sentences, and word problems, along with their semantic and functional properties.

Algebraic expressions:

- *сума трьох чисел* // sum of three numbers (nominalization)
- *різниця квадратів* // difference of squares (nominalization)
- *віднімання від'ємних чисел* // subtraction of negative numbers (nominalization + verbalization)
- *ділення многочлена на одночлен* // division of a polynomial by a monomial (nominalization + verbalization)

Task 1. Rewrite each expression using a different syntactic derivative (e.g., verbalization instead of nominalization). Discuss how the new form changes the emphasis or perspective on the mathematical operation.

Algebraic sentences:

- *Добуток двох чисел дорівнює 48.* // The product of two numbers equals 48. (nominalization)
- *Квадрат суми дорівнює сумі квадратів плюс подвоєний добуток.* // The square of a sum equals the sum of the squares plus twice the product. (multiple nominalizations)
- *Якщо до числа додати 5, то отримаємо 12.* // If you add 5 to a number, you get 12. (verbalization with conditional clause)
- *Число, збільшене на 3, дорівнює 10.* // A number, increased by 3, equals 10. (verbalization with the participial phrase)

Task 2. Identify the syntactic derivatives in each sentence and explain their function (e.g., to condense information, to highlight a particular operation). Then, rewrite the sentence in a more expanded form, using additional clauses or phrases to express the relationships among quantities.

Word problems:

- *Сума довжин усіх сторін трикутника дорівнює 35 см. Одна сторона на 5 см довша за другу, а третя сторона на 3 см коротша за другу. Знайдіть довжини сторін трикутника.* // The sum of the lengths of all sides of a triangle equals 35 cm. One side is 5 cm longer than the second, and the third side is 3 cm shorter than the second. Find the lengths of the sides of the triangle. (nominalizations, comparatives)
- *На трьох полицях було 42 книжки. Коли з першої полиці перенесли на другу 3 книжки, а з третьої на першу 5 книжок, то на всіх полицях стало порівну книжок. Скільки книжок було на кожній полиці спочатку?* // There were 42 books on three shelves. When 3 books were moved from the first shelf to the second, and 5 books from the third shelf to the first, then all shelves had an equal number of books. How many books were on each shelf initially? (multiple clauses, temporal and conditional relationships)

Task 3. Solve each word problem, showing your reasoning and calculations. Then, identify the key syntactic structures that convey the mathematical relationships in the problem and discuss how they support the problem-solving process.

These examples and tasks provide a glimpse into the rich linguistic environment that students navigate when learning and applying mathematical concepts in the Ukrainian language. By analyzing the structure and function of syntactic derivatives in authentic contexts, students can develop a deeper understanding of the language of mathematics and its role in problem-solving.

Additionally, students can practice the cognitive and communication abilities required for mathematical reasoning and expression by working on assignments that require them to manipulate and alter verbal structures. These exercises can be included in math and language arts classes, offering chances for reinforcement and cross-disciplinary learning.

4.4. Pedagogical implications and strategies

The findings of this study suggest several pedagogical implications and strategies for leveraging the role of syntactic derivatives in the formation of mathematical competence among secondary school students:

1. Explicit instruction in the structure and function of syntactic derivatives, particularly nominalizations and verbalizations, can help students recognize and manipulate these forms in algebraic expressions and problem situations. This can involve targeted lessons on the morphological and syntactic processes involved in derivation and guided practice in transforming expressions and sentences using these processes.
2. Integration of language arts and mathematics curricula can provide opportunities for students to explore the connections between linguistic structure and mathematical meaning. For example, teachers can use authentic texts that involve mathematical concepts or problems as a basis for language analysis and discussion, or conversely, use mathematical expressions and equations as a basis for language practice and production.

3. Encouragement of verbalization and explanation of mathematical thinking, both in oral and written form, can help students consolidate their understanding of syntactic derivatives and their role in problem-solving. This can involve prompts for students to describe their solution strategies, justify their reasoning, or critique the arguments of others using precise and varied linguistic forms.
4. The use of visual and graphical representations, such as concept maps, flowcharts, or diagrams, can support students' comprehension and production of complex syntactic structures in mathematical contexts. These representations can help to break down the components of a derivational process, illustrate the relationships among different elements, or provide a scaffold for organizing and expressing mathematical ideas.
5. Provision of linguistic support and accommodations for students who may struggle with the complex syntax of mathematical language, particularly those learning Ukrainian as a second language or with language-based learning disabilities. This can involve supplementary instruction in key vocabulary and structures, the use of glossaries or reference materials, or modification of problem texts to reduce linguistic complexity while preserving mathematical content.

Teachers who employ these strategies consistently and methodically can assist students in developing the linguistic competencies that support mathematical reasoning, communication, and problem-solving, as well as the mathematical knowledge and skills necessary for success in school and beyond.

5. Conclusion

In this study, we have explored the role of syntactic derivatives in the formation of mathematical competence among secondary school students learning the Ukrainian language. Through a combination of theoretical perspectives and empirical analysis, we have shown how nominalizations, verbalizations, and other linguistic transformations are integral to the representation, manipulation, and communication of mathematical concepts and relationships.

Our findings suggest that the study of syntax, particularly in the context of algebraic expressions, sentences, and word problems, can provide a powerful resource for developing students' mathematical understanding and problem-solving skills. By examining the structure and function of syntactic derivatives in authentic mathematical texts, students can gain insight into the ways in which language encodes and organizes mathematical meaning.

Furthermore, by engaging in tasks that involve the production and transformation of linguistic structures, students can practice the cognitive and communicative skills needed for mathematical reasoning and expression. These tasks can range from simple rewrites of algebraic expressions to more complex analyses of word problems, providing opportunities for students to apply their linguistic and mathematical knowledge in integrated ways.

To support this type of language-based mathematics instruction, we have proposed a set of pedagogical strategies that emphasize explicit attention to linguistic form and function, integration of language arts and mathematics curricula, verbalization and explanation of mathematical thinking, use of visual and graphical representations, and provision of linguistic support and accommodations. These strategies are grounded in the theoretical perspectives of competence, activity, functional-stylistic, and cognitive approaches to language and mathematics learning.

However, we also acknowledge the limitations of our study, particularly in terms of the scope and generalizability of our findings. Our analysis focused on a specific set of linguistic structures and mathematical concepts in the Ukrainian language and may not fully capture the diversity of syntactic and semantic features that arise in other languages or mathematical domains. Additionally, our study relied primarily on qualitative textual analysis methods and did not directly assess the impact of our proposed pedagogical strategies on student learning outcomes.

Therefore, future research in this area should expand the range of linguistic and mathematical phenomena under investigation and incorporate more quantitative and experimental methods

to evaluate the effectiveness of language-based instructional interventions. This could involve cross-linguistic comparisons of syntactic structures in mathematical texts, longitudinal studies of student language and mathematics development, or randomized controlled trials of specific pedagogical approaches.

Moreover, future work should also consider the social, cultural, and political dimensions of language and mathematics education, particularly in multilingual and multicultural contexts. This could involve examining the ways in which students' linguistic and cultural backgrounds shape their mathematical experiences and identities or exploring the role of language policies and practices in promoting or hindering access to mathematical knowledge and success.

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