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Junior high school students' onto-semiotic approach in solving AKM-oriented algebra numeracy problems based on VARK learning styles

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Abstract

This qualitative phenomenological study examines how eighth-grade students with different VARK learning styles apply the onto-semiotic approach to solve AKM-oriented algebra problems. Using purposive sampling, data were collected through tests, questionnaires, interviews, and documentation, focusing on key mathematical objects: language, context, concepts, propositions, procedures, and arguments. The findings indicate that visual, auditory, and kinaesthetic learners demonstrate stronger abilities in linking contextual problems to mathematical models, interpreting symbols, identifying variables, and correctly applying substitution. They also construct meaningful algebraic propositions that align with the problem contexts. In contrast, read/write learners tend to rely on procedural and mechanical steps, often overlooking conceptual understanding and struggling to connect contextual information with symbolic representation. Consequently, although they may arrive at correct numerical solutions, their grasp of relationships between variables in linear equations remains limited.

Keywords

AKM, algebra, numeracy, onto-semiotic approach, VARK learning styles

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Introduction

In the 21st century educational landscape, developing students' numeracy skills has become an essential focus of mathematics education worldwide. Numeracy, which encompasses the ability to apply mathematical knowledge in everyday contexts, is crucial for students' success in both academic and professional environments. In Indonesia, the Minimum Competency Assessment (AKM) serves as a key evaluation tool to measure not only students' mathematical competencies but also their ability to reason, problem-solve, and apply mathematical concepts in real-world situations (Aswita et al., 2022). The Minimum Competency Assessment (AKM) emphasizes a deeper understanding of mathematical principles, moving beyond rote memorization and focusing on their application across various contexts. However, research indicates that Indonesian students continue to face challenges in meeting these expectations, particularly in algebraic problem-solving (Fitri & Effendi, 2023). These challenges have prompted a closer examination of the approaches and strategies employed in teaching algebra and numeracy.

One of the central areas of difficulty for students is algebra, which plays a critical role in numeracy education. Algebraic reasoning is foundational for understanding higher mathematics and for problem-solving across fields such as science, economics, and engineering (Kaput, 2017, Sibgatullin et al., 2022). A study by Mullatifa (2023) highlights that students' struggles with algebraic concepts often stem from their inability to connect contextual information to abstract mathematical symbols and representations. This gap in understanding is a significant barrier to achieving mathematical literacy and performing well in assessments like AKM. As such, there is a need for effective instructional strategies that help students bridge this gap, particularly in algebra.

Recently, the Onto-Semiotic Approach (OSA) has emerged as a promising framework for addressing these issues. The Onto-Semiotic Approach (OSA) emphasizes the role of semiotics—symbols, diagrams, and other representations—in students' understanding of mathematical concepts. By focusing on the interpretation and manipulation of mathematical objects, the Onto-Semiotic Approach (OSA) encourages students to engage with algebra not just procedurally but also conceptually, fostering a deeper understanding of the underlying principles (Font & Gutiérrez, 2021). Through OSA, students are encouraged to explore how mathematical symbols and real-world contexts are connected, facilitating a more comprehensive approach to solving algebraic problems.

Despite its potential, the application of the Onto-Semiotic Approach (OSA) in the classroom, especially in algebra, remains underexplored, particularly in Indonesian schools. Most research on the Onto-Semiotic Approach (OSA) has focused on its use in higher education and university-level mathematics (Gutiérrez, 2018), with fewer studies addressing its impact at the junior high school level. Furthermore, while the Onto-Semiotic Approach (OSA) offers a powerful framework for understanding students' mathematical reasoning, its application warrants further exploration in relation to real-world assessments such as AKM, which test not only procedural knowledge but also students' ability to apply mathematics in everyday contexts.

As students' learning styles significantly influence their problem-solving approaches, integrating learning style theories with the Onto-Semiotic Approach (OSA) offers a novel way to tailor instruction to diverse needs. The VARK model (Visual, Auditory, Read/Write, Kinesthetic), developed by Fleming (2001), categorizes learners based on their preferred methods of receiving and processing information. Previous studies have shown that students' learning styles impact how they engage with mathematical concepts. For example, visual learners tend to excel when working with diagrams and symbolic representations, while kinesthetic learners benefit from hands-on activities and interactive problem-solving. Auditory learners often thrive in verbal explanations and discussions, while read/write learners excel with written content and procedures. The integration of VARK learning styles with the Onto-Semiotic Approach (OSA) offers a more personalized approach to teaching algebra, allowing educators to design lessons that cater to students' preferences while promoting a deeper understanding of algebraic concepts.

Incorporating VARK into the teaching of algebra using the Onto-Semiotic Approach (OSA) could significantly improve students' algebraic reasoning. For instance, visual learners may benefit from using diagrams and graphs to connect contextual information with algebraic symbols, while kinesthetic learners might engage more effectively with interactive, problem-solving activities. Similarly, auditory learners could benefit from discussing mathematical concepts aloud, while read/write learners could focus on written explanations and structured steps. By integrating these styles with the Onto-Semiotic Approach's (OSA) focus on semiotic representations, this approach could offer a more holistic understanding of algebraic concepts, particularly in solving AKM-oriented problems.

This research aims to explore how junior high school students, categorized by VARK learning styles, use the Onto-Semiotic Approach to solve algebraic numeracy problems aligned with Minimum Competency Assessment (AKM) objectives. Specifically, the research examines the relationship between students' learning styles and their ability to apply the Onto-Semiotic Approach (OSA) to problem-solving. The research will focus on eighth-grade students at a crucial stage of algebraic learning and will employ a qualitative methodology that includes written tests, interviews, and observations. The results of this study could provide valuable insights into how different learning styles impact students' mathematical reasoning, particularly in the context of algebra, and how educators can better support students by tailoring instruction to their individual learning preferences.

Moreover, this study aims to contribute to the broader conversation on how learning styles and mathematical reasoning intersect, especially in the context of algebra and numeracy. As noted by Tuan et al. (2022), integrating learning styles with teaching strategies can improve students' engagement and performance. While many studies have explored learning styles in the context of general education, fewer have examined how these styles interact with specific instructional approaches, such as the Onto-Semiotic Approach (OSA), especially in subjects like algebra. By addressing this gap, this study aims to provide actionable insights that can inform teaching practices in Indonesian junior high schools and beyond.

Recently, the role of digital technology in education has become increasingly important. The advent of online learning platforms and digital tools has revolutionized the way students access and engage with educational content. According to Martinez et al. (2022), digital learning environments offer new opportunities for students to engage with content in various

formats, which can be particularly beneficial for students with different learning preferences. The integration of digital tools with the Onto-Semiotic Approach could further enhance students' ability to connect real-world contexts to mathematical concepts, providing a more dynamic and interactive learning experience. As such, future research could explore how digital tools can be incorporated into the Onto-Semiotic Approach (OSA) to better support students' algebraic reasoning and numeracy development.

This study's integration of the Onto-Semiotic Approach (OSA) and VARK provides a comprehensive framework for understanding how students' learning preferences influence their algebraic problem-solving abilities. By examining how students with different learning styles approach algebraic numeracy problems, this research will provide important details about how algebra can be taught more effectively to diverse student populations. Furthermore, the findings could have broader implications for the development of personalized teaching strategies in other areas of mathematics education, providing a pathway for more inclusive and effective teaching practices.

Methodology

This study employed a qualitative research methodology, which is appropriate for understanding complex phenomena through in-depth analysis and interpretation. The data could not be quantified, necessitating a qualitative approach to deepen exploration of the participants' lived experiences. Specifically, this study used a phenomenological approach to investigate how junior high school students engage with algebraic numeracy problems, specifically within the context of the Onto-Semiotic Approach (OSA) and VARK learning styles. According to Creswell and Creswell (2017), phenomenological research focuses on describing individuals' lived experiences of a phenomenon, thereby enabling a deeper understanding of the cognitive processes involved.

The research was conducted with eighth-grade students at a public junior high school in Cirebon Regency, Indonesia. A total of 34 students participated in the research, selected through purposive sampling. Purposive sampling was used to ensure that students with varying levels of numeracy skills, reflective of different VARK learning styles (Visual, Auditory, Read/Write, Kinaesthetic), were included. This sampling method was intended to allow a diverse range of students to be examined, ensuring that the research examined how different learning styles influence the application of the Onto-Semiotic Approach in solving AKM-related algebraic problems. The participants in this study were eighth-grade students involved in the Minimum Competency Assessment (AKM) assessment, as they had sufficient learning experience and could be categorized into the four VARK learning styles.

Additionally, to collect data, a written numeracy test was administered, followed by interviews with four selected students. The test included algebraic problems related to Minimum Competency Assessment (AKM)-oriented tasks, and the interviews aimed to explore students' reasoning and problem-solving processes. The written test was validated by two professors of mathematics education from the Universitas Pendidikan Indonesia to ensure its appropriateness for the research.

The primary data collection methods for this study were written tests, questionnaires, interviews, and documentation. First, the students completed a written test with algebraic

numeracy problems. The test questions focused on the Algebra domain and were designed to assess students' ability to solve problems using the Onto-Semiotic Approach. Prior to administering the test, the questions were validated by mathematics education experts to ensure alignment with the research objectives and the Minimum Competency Assessment (AKM) framework.

In addition to the written test, students filled out a VARK learning style questionnaire. The VARK questionnaire consisted of 16 questions, adapted from the VARK Version 8.01 (Fleming, 2001). The questionnaire responses allowed the researcher to categorize students by preferred learning style (Visual, Auditory, Read/Write, Kinaesthetic).

Based on the written test results and the VARK questionnaire, four students, one from each learning style, were selected for in-depth interviews. These interviews provided further insight into how students approached the algebraic problems and their thought processes during problem-solving. The interviews aimed to understand how students with different learning styles utilized mathematical representations and semiotic tools in their problem-solving strategies. Documentation was also employed to verify the authenticity and real-life context of the research. This included classroom observations and notes from the mathematics teacher, which helped contextualize students' interactions and responses during data collection.

Written tests, questionnaires, interviews, and documentation were used to collect data in this study. The written test, consisting of numeracy (algebra) questions, was used to assess students' numeracy skills in the algebra domain. Before being administered to students, the test questions were validated by two professors of mathematics education at the University of Indonesia. The VARK learning style questionnaire was given to the respondents/students to determine the learning style tendencies of the students being studied. The VARK learning style questionnaire consisted of 16 questions. These 16 questions were adapted from the VARK Version 8.01 questionnaire (https://vark-learn.com/kuesioner-vark/) developed by Fleming in 2020. After the researcher analysed students' answers to numeracy test questions in the algebra domain using the Onto-Semiotic Approach, several students were selected based on their learning styles (visual, auditory, read/write, and kinaesthetic). Then, interviews were conducted with four selected subjects to strengthen the evidence from the students' answers. Documentation was used to provide authentic evidence that the Research was carried out in real conditions. The indicators for this numeracy test were based on those described by Kemendikbud (2017). The mathematical objects of the Onto-Semiotic Approach in this study are those described by Godino et al. (2007).

This study focuses on triangulation techniques to enhance data validity. By comparing interview results, numeracy and algebra tests, and documentation, the validity of the data in this study was tested through triangulation. The process of qualitative data analysis consists of three main stages: data reduction, data presentation, and conclusion drawing (Miles et al., 1992). Selection, focus, simplification, and abstraction of raw data are all aspects of data reduction, where the researcher selects relevant data and eliminates unnecessary information. Data presentation includes the results of data reduction, grouped by numeracy ability indicators and learning styles (VARK), presented in narrative text and tables. The results of the student interviews are also presented in brief descriptions. Conclusions are then drawn from the data presentation to determine how the numeracy skills of junior high school

students are addressed using the Onto-Semiotic Approach in solving Minimum Competency Assessment (AKM)-oriented algebra domain questions. The flow of this research is illustrated in Figure 1.

Table 1. *Mathematical objects in the onto-semiotic approach*

Aspect	Indicator
Language	Includes terms, symbols, and tables present in the problem and used to solve numeracy problems in the algebra domain.
Context	Understanding mathematical problems and designing a solution plan to solve numeracy problems in the algebra domain.
Concept	Includes the definition or description of a concept used to solve numeracy problems in the algebra domain.
Proposition	Includes the properties or principles consisting of several facts within the numeracy concept in the algebra domain.
Procedure	Includes strategies and steps used to solve numeracy problems in the algebra domain.
Argument	Includes statements used to justify answers in solving numeracy problems in the algebra domain.

Source: (Godino et al., 2007)

Findings

The findings of this study reveal the impact of VARK learning styles on eighth-grade students' ability to solve Minimum Competency Assessment (AKM)-oriented algebraic numeracy problems, particularly within the Onto-Semiotic Approach (OSA) context. A total of 34 students participated in the research, and after analyzing responses to the VARK questionnaire, they were categorized by dominant learning style. The breakdown of learning styles is as follows: 2 students with a visual learning style, 8 with an auditory learning style, 5 with a read/write learning style, 1 with a kinesthetic learning style, and 18 with a mixed learning style.

From the 34 students, four were selected for in-depth analysis, each representing one of the four main learning styles (Visual, Auditory, Read/Write, Kinesthetic). The selection of these students was based on their performance in the algebra numeracy test, their learning style profile, and teacher recommendations. Table 3 below presents the student subjects based on their respective VARK learning styles.

Table 2. *Selected subjects based on VARK learning styles*

Student Code	Subject Code	Cognitive Style
S24	V1	Visual
S20	A1	Auditory
S17	R1	Read/Write
S23	K1	Kinesthetic

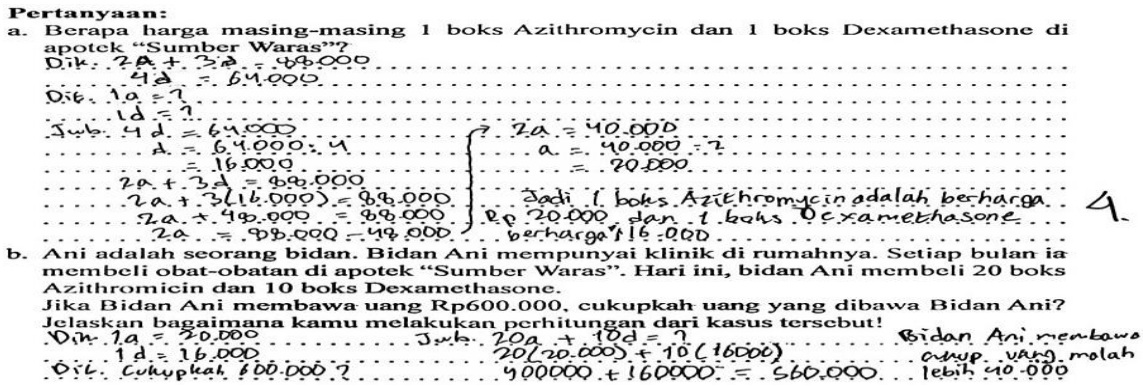
Note: V1 = Visual, A1 = Auditory, R1 = Read/Write, K1 = Kinesthetic

Student performance by learning style

Visual learning style

The visual learner demonstrated a strong ability to link contextual information to mathematical models, as evidenced by responses to questions a and b (Figure 3). The student used algebraic symbols such as "a" and "d" to represent the costs of azithromycin and dexamethasone, respectively, demonstrating a clear understanding of how contextual information can be translated into mathematical symbols. The student successfully transformed a real-world problem into a symbolic representation, demonstrating proficiency in algebraic problem-solving.

Figure 1. *The work results of the visual learning style subject*



Further analysis through the interview (Figure 2) supported the student's ability to identify variables and use substitution correctly. The student also demonstrated a strong grasp of linear equations and applied the substitution method to solve the problem. These findings align with the student's capability to connect context, language, and mathematical procedure effectively.

Figure 2. *Interview transcript with a visual learning style subject*

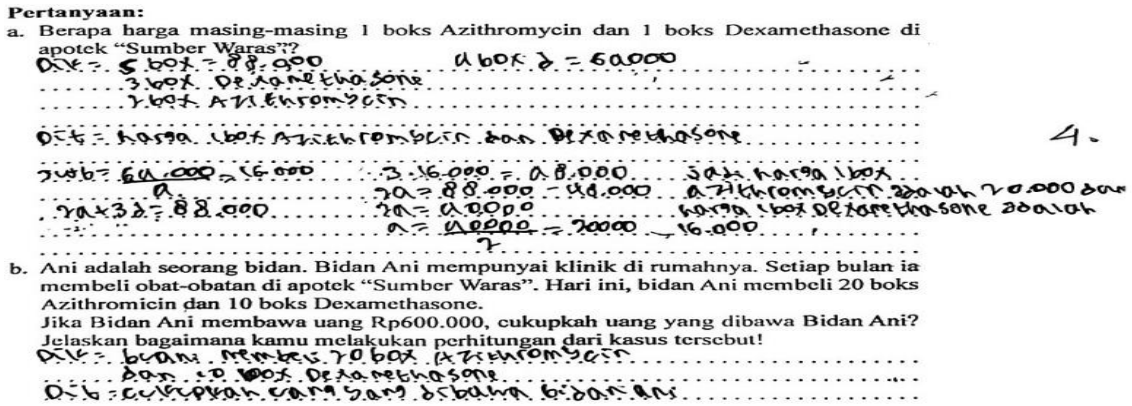
R : What does the writing 4d mean here? What does 2a + 3d mean, seno?
SV : To make it easier, sir. A symbolizes azithromycin, and the d represents dexamethasone.
R : If I change it to something else, is that okay? For example, 2x plus 3y, is that okay?
SV : Yes, that's fine.

Auditory learning style

Similarly, the auditory learner demonstrated a strong understanding of the problem context and successfully applied algebraic symbols to represent the given quantities, as seen in their work on questions a and b (Figure 4). The student used "a" and "d" to represent the cost of the medications, just as the visual learner did. The auditory learner's process also highlighted

an understanding of the relationship between contextual elements and their mathematical representation.

Figure 3. *The work results of the auditory learning style subject*



However, despite performing well on procedural tasks, the auditory learner struggled slightly to explain the conceptual foundation of their steps, as indicated in the interview transcript (Figure 4). This suggests that, while the student could complete the problem, their understanding of the underlying concepts was less developed than that of the visual learner.

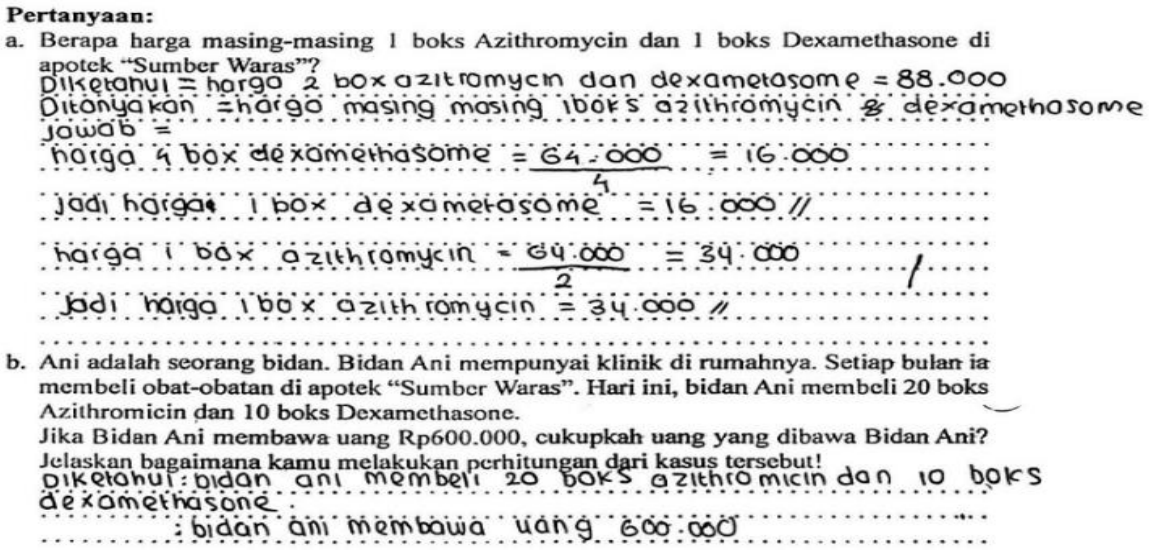
Figure 4. *Interview transcript with an auditory learning style subject*

R : I see here 2a + 3d = 88 thousand, what does that mean, Rud?
SA : 2a represents 2 boxes of azithromycin and 3d represents 3 boxes of dexamethasone. So, a represents azithromycin and d represents dexamethasone.
R : Why did you choose a and d, Rudi? Why not something else?
SA : Because of the initial letters.
R : If I change it to 2x plus 3y, is that ok
SA : Yes, that's fine.
R : According to you, Rudi, what do a and d represent?
SA : Variables.
R : What about 2a, what does the 2 represent?
SA : A coefficient.

Read/write learning style

The read/write learner's performance differed significantly from the visual and auditory learners. These students did not use algebraic symbols in their solution (Figure 5). Instead, they provided a written procedure without translating the contextual information into mathematical variables, indicating a lack of understanding of the symbolic nature of algebra. The students' responses were more mechanical, focusing on procedural steps rather than the conceptual or symbolic relationships among the quantities.

Figure 5. *The work results of the read/write learning style subject*



In interviews, the read/write learner struggled to contextualize the problem, failing to connect the medication prices to the corresponding quantities. This student's approach was largely focused on written steps, without the deeper conceptual understanding of how to represent the problem algebraically. Their inability to develop a proper conceptual framework for the problem is a common limitation for students with a read/write learning style, as they tend to focus more on written texts and memorization than on visual or kinesthetic representations of concepts.

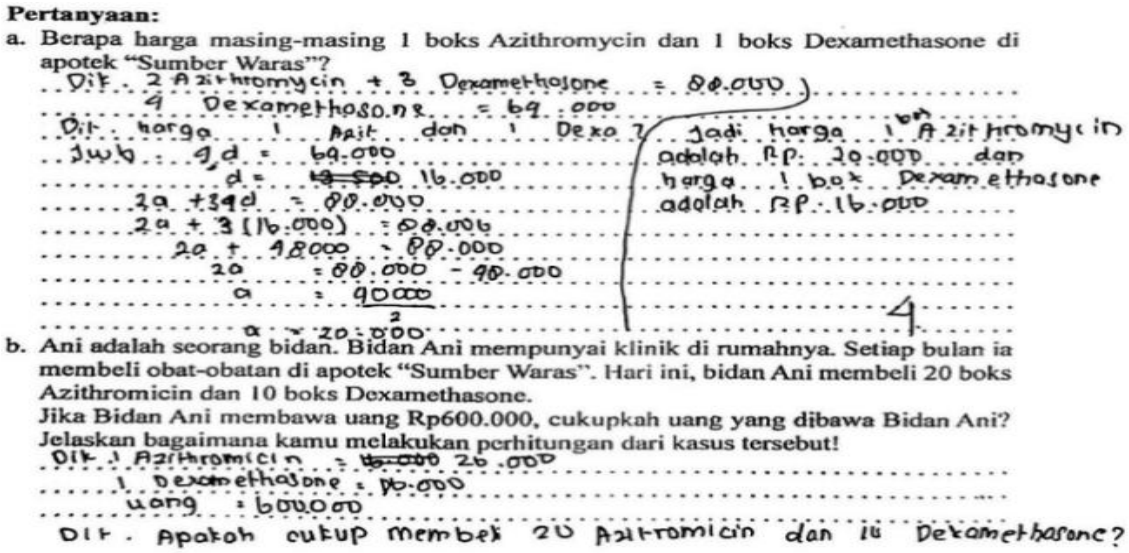
Figure 6. *Interview transcript with read/write learning style subject*

R : According to Aulia, in question number 1, are there any mathematical symbols that Aulia understands?
SR : Yes. This one, the subtotal, uh, the 64 thousand.
R : Are there any other mathematical symbols?
SR : Yes, the number and the equal sign.

Kinesthetic learning style

The kinesthetic learner demonstrated a similar ability to connect the contextual problem to algebraic symbols as the visual and auditory learners. However, unlike the read/write learner, the kinesthetic student was able to effectively model the problem mathematically. Their process involved translating the real-world situation into algebraic symbols and solving the problem using the substitution method, as shown in their work on questions a and b.

Figure 7. *The work results of the kinesthetic learning style subject*



In the interview (Figure 8), the kinesthetic learner explained their use of symbols to represent the cost of medications, and how they utilized substitution to solve the system of equations. They demonstrated an understanding of the procedure and a hands-on approach to problem-solving, often using physical manipulation of variables in their explanations.

Figure 8. *Interview transcript with kinesthetic learning style subject*

R : Rafael, in question number 1, did you find any mathematical symbols?
SK : Yes, for example *d* and *a* as variables.
R : What about the word *apotek* and the word *resi*, are those symbols?
SK : No.
R : Rafael, earlier these were used as an example. In mathematical terms, what are *d* and *a* called?
SK : They're called variables.
R : Is it okay if in the example we don't use *d* and *a*, but use *x* and *y* instead?
SK : Yes, that's fine, we can.

Based on the analysis of the four student cases, the research found that students with visual, auditory, and kinesthetic learning styles exhibited a better understanding of the algebraic problem context and were more adept at translating real-world situations into symbolic representations. These students demonstrated the ability to identify variables, use substitution methods, and construct algebraic propositions aligned with situational meaning. On the other hand, the read/write learner focused more on written procedures and mechanical steps, often neglecting a deeper conceptual understanding of the problem. This highlights the varying degrees to which different learning styles can influence students' abilities to apply the Onto-

Semiotic Approach in solving the Minimum Competency Assessment (AKM)-oriented algebra problems.

Discussion

Language

Students with visual, auditory, and kinesthetic learning styles can explicitly differentiate between mathematical symbols and everyday words. They recognize a and d as mathematical symbols that function as variables. They even mention that variables can be replaced with other letters, such as x and y, which demonstrates their flexibility in understanding the sign system. From the perspective of the onto-semiotic approach, this means they activate the language objects (sign system) quite effectively, transitioning from natural language to symbolic language and understanding the specific function of symbols in constructing mathematical meaning. This aligns with the findings of Font and Gutiérrez (2007), who state that symbolic representation plays a central role in the construction of mathematical objects and meaning.

Students with a read/write learning style experience a different condition. These students do not transform the contextual problem in the question into a mathematical model. They find answers through informal reasoning, directed guessing, calculation patterns, or everyday logic. They do not use algebraic representations, so the context is not translated into variables and equations. This is a condition that often arises in algebra learning. Nathan & Pittalis (2023) show that students often choose direct arithmetic strategies because they seem easier than constructing an algebraic model. Additionally, these students do not seem to understand algebra as a mathematical language to represent real-world situations. They solve problems arithmetically because formal representation is considered unimportant. Beeh et al. (2018), Booth et al. (2016), and Lange et al. (2014) found that many students lack a mental schema linking variables to real-world quantities. This means that, even though they can solve the problem correctly, they do not write out a model because they do not understand the functional value of algebraic symbols.

Context

Students with visual, auditory, and kinesthetic learning styles can identify from the start that the problem is related to algebra. They can also mention the information given and what is being asked. This shows that students with visual, auditory, and kinesthetic learning styles build a relatively complete mathematical situation. These students grasp the relevant quantitative relationships and separate them from irrelevant contextual details. This ability aligns with the demands of contemporary numeracy literacy, which emphasize interpreting real-world contexts and translating them into mathematical models, particularly in algebraic word problems (Tutratan et al., 2024).

The condition for students with a read/write learning style is different. These students appear to read the problem but have not yet built a situational and symbolic understanding. Specifically, this occurs with students who, with a read/write learning style, are unable to link

written information about the price of medication and the purchase receipt into a linear equation, nor are they able to clearly inventory what is known and what is being asked. Theoretically, this condition relates to two major domains: First, the theory of understanding word problems and mathematical modeling. Second, the characteristics of the read/write learning style according to the VARK framework.

First, consider the cognitive perspective of understanding the problem. Verschaffel et al. (2020) explain that when working on a word problem, a person needs to build several layers of mental representation. There is a text-based representation, then a situational model that describes the real-world context, and only then a symbolic mathematical model. If the student stops at the text level, they retain only fragments of sentences and numbers, without truly seeing the story's underlying relational structure. The fact that students do not connect the price of medication to the information on the purchase receipt indicates that the situational model has not yet fully formed. They see the price of the medication, the number of packages, and the total on the receipt as separate data, rather than as an interconnected system that could be represented by a linear equation, such as the total cost as a linear combination of several types of medication. This is consistent with the findings of Cummins et al. (1988), which indicate that the main difficulty for children with word problems often arises from their failure to understand the language and abstract relationships within the text rather than the arithmetic operations. From a mathematical modeling perspective, Blum and Leiß (2007) describe a modeling cycle that includes understanding the real-world situation, simplifying, mathematizing, working with the model, reinterpreting, and validating. If the student does not connect the price of medication with the data on the receipt to form a linear equation, it means they stop at the text phase or merely "read the story" without making the leap to mathematizing, i.e., turning the situation into a symbolic relationship.

Second, from the perspective of the read/write learning style in the VARK model. Fleming and Mills (1992) define read/write as a tendency for students to feel more comfortable learning through written texts, notes, books, and verbal symbols, rather than through visual or kinesthetic activities. In the case of the medication price and purchase receipt problem, a student with a read/write learning style who has not yet understood the context will likely keep reading the problem, perhaps even copying the numbers onto their answer sheet, but will stop at the level of quoting information without organizing it. They do not create a list of what is known and what is being asked; they do not structure the information into pairs such as type of medication, quantity, unit price, and total; and they do not rewrite it in symbolic form, such as by assigning variables to the price of each medication or to the number of boxes. However, for students who are more advanced in modeling, this step becomes the main bridge between the narrative of the purchase receipt and the linear equation that represents the purchasing situation.

Concepts, propositions, and procedures

Students with visual, auditory, and kinesthetic learning styles can mention the term "variable" and use it correctly to refer to *"a" and "d."* They also refer to substitution as the concept used when the value of a variable is known and then substituted into the previous equation. Although their explanation is still procedural, there are indications that they

understand substitution as an operation on equations rather than just a mechanical calculation step.

At the propositional level, students with visual, auditory, and kinesthetic learning styles formulate relationships in the form of linear equations: 2a + 3d = 88,000 to represent the combination of the prices of two types of medication on the first receipt; 4d = 64,000 for the second receipt. This indicates that they can build algebraic propositions consistent with the situational meaning. Amin et al. (2018) state that students with stronger mathematical abilities tend to have a richer, more consistent network of concepts and propositions within the onto-semiotic framework. The pattern shown aligns with this profile, though it remains limited to simple linear equation systems.

The main strategy of students with visual, auditory, and kinesthetic learning styles is to solve the equation 4d = 64,000 to get d = 16,000, then substitute that value into the first equation:

$$2a + 3d = 88{,}000 \Rightarrow 2a + 3(16{,}000) = 88.000$$
$$2a + 48{,}000 = 88{,}000 \Rightarrow 2a = 40{,}000 \Rightarrow a = 20{,}000$$

This procedure is consistent with the substitution method formally taught in schools. In the terminology of the onto-semiotic approach, the student performs a series of operational practices that are relatively efficient and free of arithmetic errors.

Research by Wibowo et al. (2024) shows that, in solving mathematical problems, students who can link procedures to situations and concepts tend to exhibit more complete stages of the onto-semiotic approach, including understanding the situation, modeling, transforming, and interpreting. In this student's case, the stages of modeling and transformation appear strong, while the final interpretation aspect (e.g., rechecking or reflecting on the answer) has not been fully addressed in the oral explanation.

However, students with a read/write learning style do not demonstrate the conceptual or propositional stages (in the onto-semiotic approach) when solving a system of linear equations, as explained. From a learning-style perspective, students with a read/write style tend to focus on procedural steps and ignore a deeper understanding of the concepts. They may memorize the substitution procedure without truly understanding why these steps work or what the relationship between the variables is in a broader context. Research shows that the read/write learning style is more successful at solving problems when the focus is procedural (as in this problem), but they often neglect deeper mathematical relationships (Kanadlı, 2016).

From the perspective of the onto-semiotic approach, mathematical understanding involves not only mastering procedures or symbols but also understanding concepts (e.g., the relationship between variables or broader mathematical relationships) and visual representations that can enrich that understanding. This approach emphasizes that, to achieve a deeper understanding, students must be able to link mathematical symbols to the meanings of broader concepts and build conceptual objects connected to the relationships between variables. In this case, the read/write learning style student only follows procedures without building conceptual objects, which prevents them from developing a deeper understanding of the structure of relationships between variables in the system of linear equations.

Argument and justification

The argument dimension is an intriguing aspect to consider. Students with visual, auditory, and kinesthetic learning styles can explain step-by-step how they move and divide in the equations, but the justifications provided are still procedure-oriented (just insert, just divide) without addressing the conceptual reasons why those steps are valid algebraically (e.g., the property of equality or inverse operations). From the perspective of the onto-semiotic approach, an argument ideally connects procedures with the underlying concepts and propositions.

Furthermore, when asked about the possibility of a different answer from a peer, they confidently assert that their answer is correct without mentioning verification strategies such as comparing results, substituting back into the context, or discussing. This shows that argumentative practices at the level of personal meaning are still dominated by personal belief and are not strongly connected to institutional mathematical argument standards (e.g., proof by substitution or model consistency check). This contrast echoes the findings of Mifta Junidhar et al. (2024), who found that students often seem confident in their answers but are less consistent in concluding and validating the relationship between the question and the answer.

Conclusion

This study explores the relationship between students' VARK learning styles and their ability to solve algebraic numeracy problems in the context of the Minimum Competency Assessment (AKM), utilizing the Onto-Semiotic Approach (OSA). The findings reveal that visual, auditory, and kinaesthetic learners demonstrated greater effectiveness in engaging with algebraic problems by translating contextual information into algebraic symbols and solving them using appropriate mathematical procedures. These learners demonstrated a deeper conceptual understanding and applied the semiotic tools suggested by the Onto-Semiotic Approach (OSA) to interpret and represent algebraic problems effectively.

In contrast, read/write learners primarily relied on written procedures, struggling to link contextual information with mathematical symbols. This highlights the limitations of a predominantly read-and-write learning style when solving algebraic problems that require symbolic thinking and abstract reasoning. The research underscores the importance of incorporating multimodal teaching strategies that accommodate students' diverse learning styles, particularly through visual aids, interactive activities, and verbal explanations, to foster deeper understanding and enhance algebraic problem-solving skills.

The results suggest that integrating the Onto-Semiotic Approach (OSA) with the VARK model can provide a comprehensive framework for addressing students' varying needs in mathematics education. By leveraging the strengths of each learning style, educators can better support students in developing their algebraic reasoning and numeracy skills. This research also opens avenues for future research, particularly in exploring the use of digital tools to enhance multimodal learning and examining the effectiveness of the Onto-Semiotic Approach (OSA) in other areas of mathematics education.

Overall, this research contributes to the growing body of knowledge on how learning styles influence students' mathematical abilities and provides practical implications for improving algebra instruction through differentiated and multimodal teaching approaches.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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