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Original Article

Mathematical Conceptual Understanding Profiles of Junior High School Students in Algebra Based on Visual, Auditory, and Kinesthetic Learning Styles

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Abstract

Mathematical conceptual understanding is a foundational competency in mathematics education, particularly in algebra at the junior high school level. Many students struggle with algebraic concepts, a difficulty believed to be linked to individual learning modalities. This study aimed to analyze the profiles of mathematical conceptual understanding among seventh-grade students at SMPN 23 Mataram, focusing on algebra content and examining differences across Visual, Auditory, and Kinesthetic (VAK) learning styles. A qualitative descriptive design was employed with 30 seventh-grade students categorized using a validated VAK questionnaire, from which three representative subjects were selected through purposive sampling for in-depth analysis. Data were collected through a Conceptual Understanding Test (CUT) comprising ten essay items aligned with five internationally recognized indicators, encompassing concept identification, classification, representation, application, and relational reasoning followed by individual clinical interviews. Analysis followed Miles and Huberman's interactive model with method triangulation to ensure trustworthiness. The findings revealed three distinct in-depth profiles: visual learners excelled in graphical representation and concept classification but were less precise in numerical computation; auditory learners demonstrated strong verbal concept definition and sequential procedural understanding; and kinesthetic learners showed better comprehension through manipulative activities than through abstract presentation. These results confirm that VAK learning styles significantly shape students' mathematical conceptual understanding profiles, offering meaningful insights for qualitatively oriented educational research. Mathematics teachers should therefore integrate differentiated, multi-sensory instructional approaches to address diverse learning needs comprehensively.

Keywords: Algebra, Conceptual Understanding, Differentiated Learning, Junior High School, VAK Learning Styles.

1. Introduction

Mathematics education plays a fundamental role in developing students' logical, analytical, and critical thinking patterns, as well as their problem-solving abilities. Mathematics does not only teach numerical calculations, but also trains the ability of abstraction, reasoning, and concept representation. The importance of mathematics is reflected in its position as a compulsory subject at all levels of formal education in Indonesia, from elementary school to university (Kemendikbud, 2022).

At the Junior High School (SMP) level, mathematics begins to introduce more abstract concepts compared to previous levels. One of the core materials that seventh-grade students must master is algebra. Algebra is a branch of mathematics that serves as the foundation for most advanced mathematics topics, ranging from linear functions, systems of equations, to calculus. Therefore, mastery of algebraic concepts in seventh grade becomes crucial as a foundation for students' academic continuity (Kieran, 2018).

Despite this importance, algebra learning remains a significant challenge for many students. Jupri et al. (2014) identified three primary sources of difficulty: understanding variables as representations of unknown numbers, distinguishing between variables, constants, and coefficients, and performing algebraic operations accurately. These difficulties directly undermine students' broader mathematical conceptual understanding (Unaenah et al., 2022). The National Council of Teachers of Mathematics (2000) defines conceptual understanding as the ability to identify, classify, and connect mathematical concepts, encompassing five key indicators: restating a concept, classifying objects, providing examples and non-examples, representing a concept in multiple forms, and applying concepts in problem-solving (National Council of Teachers of Mathematics, 2000).

Such difficulties are not independent of the learner; rather, research suggests that the manner in which students perceive and process algebraic information is closely tied to their individual learning modalities. A growing body of research has examined how individual differences in learning styles influence mathematics achievement. The VAK (Visual, Auditory, Kinesthetic) model, developed by Porter and Hernacki (2015), posits that individuals have a dominant sensory modality through which they most effectively receive and process information. Research by Yani et al. (2024) found significant differences in mathematical conceptual understanding profiles across the three VAK categories among senior high school students. Similarly, Akras and Pujiastuti (2025) demonstrated that learning style significantly moderates mathematical literacy ability among JHS students. Afandi and Zuraidah (2020) further confirmed that the alignment between instructional methods and students' dominant learning modality is a key determinant of engagement and learning readiness.

However, several notable research gaps remain. First, the majority of existing studies focus on senior high school or university students; systematic investigation of algebraic conceptual understanding profiles in JHS students through the VAK lens remains limited. Second, prior studies predominantly employ quantitative designs that capture score-based differences without exploring the underlying cognitive mechanisms. Third, contextual research in schools with diverse student populations such as SMPN 23 Mataram is scarce. This study was designed to address these gaps by employing a qualitative descriptive approach that combines written tests and clinical interviews to produce comprehensive cognitive profiles.

This study aimed to describe and analyze in depth the profiles of mathematical conceptual understanding of seventh-grade students at SMPN 23 Mataram on algebra content, examined through the lens of Visual, Auditory, and Kinesthetic learning styles. Specifically, the study sought to identify the strengths and weaknesses of each learning style type on each of the five NCTM-based conceptual understanding indicators. The findings are intended to contribute theoretically to the understanding of the relationship between learning modality and mathematical cognition, and practically to inform the design of differentiated, multi-sensory instructional strategies for JHS mathematics classrooms.

2. Literature Review

2.1. Mathematical Conceptual Understanding

Mathematical conceptual understanding refers to a student's ability to comprehend mathematical ideas in a meaningful and connected manner, rather than merely memorizing isolated facts or procedures (Kilpatrick et al., 2001). NCTM (2000) operationalizes this construct through five indicators applicable to algebra learning at the JHS level: (1) restating a concept in one's own words; (2) classifying objects according to mathematical properties (e.g., identifying like terms); (3) providing examples and non-examples of a concept; (4) presenting a concept in multiple mathematical representations (verbal, graphical, symbolic); and (5) applying the concept in problem-solving situations. These five indicators have been widely adopted in Indonesian mathematics education research as the operational framework for assessing conceptual understanding (Akras & Pujiastuti, 2025; Yani et al., 2024).

Algebra, as one of the most abstract topics introduced at the JHS level, presents unique challenges to conceptual understanding. Kieran (2018) characterizes early algebra learning as a transition from arithmetic thinking to structural thinking, requiring students to shift from computing with specific numbers to reasoning about general relationships represented by variables. This structural shift is cognitively demanding and is a primary source of student error and misconception (Jupri et al., 2014).

2.2. Visual, Auditory, and Kinesthetic (VAK) Learning Styles

The VAK model, as systematized by Porter and Hernacki (2015), classifies learners based on their preferred sensory modality for receiving and processing information. Visual learners prefer graphical, diagrammatic, and color-coded representations; they tend to think in images and organize information spatially. Auditory learners absorb information most effectively through listening and verbal explanation; they often internalize rules through verbal repetition and discussion. Kinesthetic learners learn best through physical engagement, hands-on activity, and concrete manipulation; they typically need direct experience with objects or movement to build understanding.

The relevance of the VAK framework to mathematics education has been substantiated by several studies. Yani et al. (2024) demonstrated that the three VAK modalities produced distinctly different profiles of mathematical conceptual understanding, with visual learners excelling in representation and auditory learners excelling in verbal conceptualization. More recently, Akras and Pujiastuti (2025) found that VAK learning style significantly moderated the effect of problem-based learning on mathematical literacy among JHS students. Meanwhile, Sugianto et al. (2022) noted that VAK-aligned instructional materials significantly improved students' engagement and learning outcomes in secondary school mathematics. These findings collectively underscore the necessity of incorporating learning style awareness into instructional design.

2.3. Differentiated Learning in Mathematics

Differentiated instruction refers to a pedagogical approach in which teachers systematically adjust the content, process, product, and learning environment in response to individual student differences in readiness, interest, and learning profile (Tomlinson, 2014). In the context of mathematics education, differentiated instruction has been shown to improve both achievement and motivation across diverse learner populations (Afilin, 2023; Harahap & Manurung, 2023). Implementing differentiated instruction based on VAK profiles requires multi-sensory pedagogical strategies: the use of visual aids (diagrams, color-coding, infographics) for visual learners; discussion, verbal explanation, and audio-based tools for auditory learners; and manipulatives, exploratory tasks, and game-based activities for kinesthetic learners (Afandi & Zuraidah, 2020; Muhlis et al., 2022).

3. Methods

3.1. Research Design

This research uses a qualitative research approach with a descriptive design (descriptive qualitative research). The selection of this approach is based on the research objective of exploring, describing, and analyzing in depth the phenomenon of students' mathematical conceptual understanding abilities from the perspective of their learning styles (Moleong, 2021). The qualitative approach was chosen because it allows researchers to obtain rich and contextual understanding of students' cognitive processes that cannot be revealed through numerical data alone (Sugiyono, 2018). The descriptive design is used to provide an accurate and systematic picture of the characteristics, patterns, and ability profiles of each learning style type.

3.2. Research Location and Time

The research was conducted at SMPN 23 Mataram, West Nusa Tenggara, in the Even Semester of the 2025/2026 Academic Year. This location was chosen purposively because: (1) this school has a high diversity of student backgrounds, making it representative for describing the heterogeneity of learning styles; (2) there is a real need from the school to develop more differentiated learning strategies; and (3) the researcher's accessibility to conduct observations and in-depth interviews.

3.3. Research Subjects

The research population was all seventh-grade students of SMPN 23 Mataram in the 2025/2026 Academic Year. The research subjects in the initial stage (grouping stage) were one purposively selected class VII, totaling 30 students. Based on the results of filling out the VAK learning style questionnaire, the following distribution was obtained: 14 students (46.67%) with a visual learning style, 9 students (30.00%) with an auditory learning style, and 7 students (23.33%) with a kinesthetic learning style. Subsequently, 1 representative subject was selected from each category through purposive sampling technique based on the criteria: (a) the most dominant learning style tendency based on questionnaire scores, and (b) the student's willingness and ability to be interviewed in depth. Thus, the total in-depth research subjects were 3 students (Visual Student/VS, Auditory Student/AS, and Kinesthetic Student/KS).

3.4. Research Instruments

This research uses three main instruments that complement each other. First, the VAK Learning Style Questionnaire adapted from the instrument developed by Porter and Hernacki (2015). This questionnaire consists of 30 statements describing everyday learning habits (10 items per modality) with a four-point Likert scale. The questionnaire is used to identify and group students based on their dominant learning modality. The validity of the instrument was tested through expert judgment by two mathematics education expert lecturers.

Second, the Conceptual Understanding Ability Test (CUAT) consisting of 10 essay questions measuring five indicators of algebraic conceptual understanding based on NCTM (2000), namely: (1) restating concepts, (2) classifying objects (like terms), (3) providing examples and non-examples, (4) presenting concepts in mathematical representations, and (5) applying concepts in problem solving. The CUAT questions were validated by three validators: one mathematics subject matter expert and two junior high school mathematics teacher practitioners.

Third, the Clinical Interview Guide used to explore more deeply the thinking processes and cognitive strategies of students in solving CUAT questions. This semi-structured interview was designed to reveal the "why" and "how" students arrive at the answers they give, as well as to identify possible misconceptions.

3.5. Data Collection Procedure

Data collection was carried out through three systematic stages. The first stage was the administration of the VAK learning style questionnaire to all 30 students to group them based on their dominant learning modality. The second stage was the administration of the CUAT to the 3 selected representative subjects under controlled conditions. Students were given 80 minutes to complete all questions individually. The third stage was the conduct of in-depth clinical interviews with each subject separately, immediately after the CUAT was completed, to obtain rich information about their thinking processes.

3.6. Data Analysis Technique

Data analysis used the interactive data analysis technique of Miles and Huberman (1994) which includes three stages: (1) data reduction, which is the process of selecting, focusing, and simplifying raw data obtained from the questionnaire, CUAT, and interviews; (2) data display, which is organizing information in an organized manner in the form of indicator score comparison tables, descriptive descriptions, and representative interview excerpts; and (3) drawing conclusions and verification, which is interpreting findings based on patterns and relationships found in the data. The validity of the data is ensured through method triangulation, namely comparing the results from all three instruments (questionnaire, test, and interview) for each subject to obtain confirmation and consistency of findings.

4. Results and Discussion

4.1. Distribution of Student Learning Styles

Administration of the VAK questionnaire to 30 seventh-grade students at SMPN 23 Mataram revealed a varied distribution of learning modalities, as presented in Table 1.

Table 1. Distribution of Learning Styles of Seventh-Grade Students at SMPN 23 Mataram

No	Learning Style Category	Frequency (Students)	Percentage (%)
1.	Visual (V)	14	46.67%
2.	Auditory (A)	9	30.00%
3.	Kinesthetic (K)	7	23.33%
	Total	30	100%

As shown in Table 1, the visual learning style was dominant (46.67%), followed by auditory (30.00%) and kinesthetic (23.33%). This distribution is consistent with Putri et al. (2021), who found visual modality to be the most prevalent among secondary school students across several regions of Indonesia. From a pedagogical standpoint, this indicates that the majority of students in this class are likely to benefit most from information presented through visual channels such as diagrams, color-coded notes, and structured written text. However, the substantial proportions of auditory and kinesthetic learners also highlight the necessity for multi-modal instructional approaches.

4.2. Conceptual Understanding Scores by Indicator

The CUT results revealed distinct score patterns across the five NCTM-based conceptual understanding indicators for each learning style representative. These data are summarized in Table 2.

Table 2. Comparison of Conceptual Understanding Scores by Indicator and Learning Style (0–100 Scale)

No	Conceptual Understanding Indicator	Visual	Auditory	Kinesthetic
1.	Restating concepts	85	90	65
2.	Classifying objects (like terms)	92	75	72
3.	Providing examples and non-examples	80	78	60
4.	Presenting concepts in representation	95	64	68
5.	Applying concepts/procedures	70	88	82

Table 2 reveals a clear pattern: each learning style type demonstrates a distinct profile of strengths and weaknesses across the five indicators, rather than uniform performance. These differential profiles are explored in detail in the following subsections.

4.3. Profile of Visual Students (VS)

The visual student demonstrated outstanding performance on concept representation (score: 95) and object classification (score: 92), which are tasks that require spatial organization and pattern recognition. In the classification task involving like terms, VS rapidly identified groupings by visually scanning the structure of each algebraic expression. This finding aligns with the fundamental characteristic of visual learners described by Porter and Hernacki (2015), the tendency to think in pictures, organize information spatially, and process diagrammatic or color-coded material efficiently.

However, VS exhibited a notable weakness in procedural application (score: 70), particularly when problems involved extended chains of arithmetic operations. Clinical interview data revealed that VS would lose track of intermediate steps when the problem lacked graphical or color-based cues. VS explicitly stated: *'It is easier for me if x and y are written in different colors, so I do not get confused when adding them.'* This observation confirms the pivotal role of visual scaffolding such as color-coded variables and structured notation for this type of learner. These findings are consistent with Yani et al. (2024), who reported that visual learners demonstrate particular strength in representational and classificatory aspects of mathematical conceptual understanding.

4.4. Profile of Auditory Students (AS)

The auditory student performed best on restating concepts verbally (score: 90) and applying concepts procedurally (score: 88). AS demonstrated strong retention of teacher verbal explanations and was able to define algebraic terms such as variable, constant, and coefficient with vocabulary precisely matching the textbook narrative. The key weakness emerged in concept representation (score: 64), where AS struggled to translate verbal understanding into graphical or symbolic forms.

During clinical interviews, AS was observed whispering procedural rules to themselves while solving algebraic problems which a strategy consistent with the auditory learner's reliance on internal verbalization. AS explained: *'I remember the teacher saying "when you move to the other side, the sign changes," so I follow that voice.'* This pattern confirms that auditory learners internalize mathematical logic through verbal mnemonics and sequential oral instructions. Afandi and Zuraidah (2020) similarly found that auditory learners' engagement and performance are maximized when instructional delivery is aligned with their dominant verbal modality.

4.5. Profile of Kinesthetic Students (KS)

The kinesthetic student scored lowest on indicators requiring theoretical recall, including restating a concept (score: 65) and providing examples and non-examples (score: 60). Abstract definition-oriented tasks proved difficult for KS, as they found rote memorization disconnected from tangible experience. In contrast, KS showed comparatively stronger performance in procedural application (score: 82), where hands-on trial-and-error strategies on scratch paper produced correct solutions.

Interview data revealed that KS expressed clear disengagement with passive lecture-based instruction: *'I prefer learning through practice or math games, it sticks better in my brain.'* KS also described finding algebra tiles (physical manipulatives) particularly helpful for visualizing algebraic grouping. These findings support the constructivist perspective emphasized by Piaget and later elaborated by Al-Tabany (2017), which holds that concrete, experiential engagement with objects precedes and scaffolds the development of abstract understanding. Muhlis et al. (2022) also found that kinesthetic learners require more intensive physical involvement including educational games and hands-on exploration to achieve optimal comprehension in mathematics.

4.6. Cross-Profile Discussion and Implications

Taken together, the three profiles substantiate the central theoretical proposition of the VAK model (Porter & Hernacki, 2015), different learning modalities produce different cognitive strengths and preferences, which manifest distinctly across the various dimensions of mathematical conceptual understanding. The present study extends the findings of Yani et al. (2024) into the specific context of JHS algebra, providing more granular indicator-level analysis than previously available.

Compared with Afilin (2023), who focused on the outcomes of a differentiated instructional intervention, the present study contributes a prior-to-intervention diagnostic picture of students' cognitive profiles. This diagnostic orientation is essential: without a clear profile of how each learning style type engages with specific conceptual indicators, instructional differentiation risks being superficial or misaligned. The findings also align with the broader literature on multi-sensory pedagogy (Harahap & Manurung, 2023; Tomlinson, 2014), which advocates for the simultaneous accommodation of multiple learning modalities in classroom instruction.

The practical implications of these findings are threefold. First, mathematics teachers should conduct VAK-based learning style assessments at the beginning of each academic semester to inform instructional planning. Second, algebra content should be presented in multi-representational formats, color-coded diagrams for visual learners, structured verbal explanations and peer discussions for auditory learners, and physical manipulatives (e.g., algebra tiles) for kinesthetic learners. Third, schools should invest in diverse instructional media to support all learning style types equitably. These implications resonate with the differentiated learning framework advocated by the Indonesian Merdeka Curriculum (Kemendikbud, 2022), which explicitly encourages student-centered and responsive pedagogy.

5. Conclusion

This study investigated the profiles of mathematical conceptual understanding in algebra among seventh-grade students at SMPN 23 Mataram through the lens of VAK learning styles. The findings established three distinct cognitive profiles. Visual learners (46.67% of the sample) excelled in mathematical representation and concept classification but required reinforcement in numerical computation accuracy. Auditory learners (30.00%) demonstrated superior verbal concept articulation and procedural sequencing, but were weaker in graphical visualization and representation. Kinesthetic learners (23.33%) required physical engagement and manipulative activities to achieve meaningful understanding, and struggled most with abstract definitional recall.

These findings confirm that VAK learning styles produce substantively distinct conceptual understanding profiles, not merely different global achievement levels. The research contributes to the literature by providing indicator-level diagnostic profiles that are more instructionally actionable than aggregate score comparisons. Theoretically, this study strengthens the argument for learning style-sensitive models of mathematical cognition. Practically, it provides an empirical basis for designing differentiated, multi-sensory mathematics instruction in JHS contexts.

This study has several limitations. The in-depth analysis involved only three representative subjects, which restricts statistical generalizability. The study was also conducted in a single school focusing on a single mathematical topic. Other variables potentially influencing conceptual understanding such as learning motivation, multiple intelligences, and socioeconomic background were not controlled.

Future research is encouraged to: (1) replicate this study with larger samples and mixed-methods designs for broader generalizability; (2) extend the VAK-conceptual understanding analysis to other mathematical domains such as geometry, statistics, and number theory; and (3) design, implement, and evaluate the effectiveness of differentiated instructional models explicitly informed by VAK profiles in improving algebra conceptual understanding, using quasi-experimental or classroom action research designs.

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