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Unveiling the roots of students' low comprehension of quadratic functions: A hermeneutic phenomenological study in a West Lombok junior high school, Indonesia

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Quadratic functions are a core topic in junior high school mathematics, yet many students continue to struggle to master this material. This study explored, in depth, the factors underlying the low comprehension of quadratic functions among eighth-grade students at a public junior high school in West Lombok Regency, Indonesia. A hermeneutic phenomenological design was used to capture students' lived experiences and interpretations of their learning difficulties, complemented by thematic analysis to identify recurring patterns across responses. Data were collected through an open-ended questionnaire completed by ten purposively selected students and analyzed following Braun and Clarke's six-phase thematic analysis, assisted by an artificial intelligence tool (ChatGPT) during initial coding and subsequently verified manually by the researchers. The analysis produced ten initial codes, condensed into five categories and, ultimately, four overarching themes: (1) difficulty in understanding basic concepts, (2) lack of participation in learning, (3) less effective teaching methods, and (4) low motivation to learn mathematics. These findings indicate that students' struggles with quadratic functions stem not merely from the material's cognitive complexity but from an interplay of cognitive, behavioral, pedagogical, and affective factors. By foregrounding students' own voices rather than relying solely on achievement scores, this study offers a more holistic understanding of algebra learning difficulties. It recommends that teachers design more contextual, participatory, and enjoyable instructional strategies, supported by visual and concrete media, to strengthen students' conceptual understanding of quadratic functions and to inform future intervention-based research.

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1. Introduction

The quadratic function is a form of polynomial function whose variable has a highest power of two, generally written in the standard form $y = ax^2 + bx + c$, with $a \neq 0$. Beyond being a compulsory topic in the school mathematics curriculum, the quadratic function plays an important role in solving real-world problems in fields such as physics, economics, and engineering (Cuoco, Goldenberg, &

Mark, 1996). Mastery of this topic is often treated as a gateway to more advanced algebraic and analytic reasoning in secondary and tertiary mathematics.

The quadratic function is also important because it represents various real-world phenomena, such as projectile motion, optimization problems, and data modeling. Working with quadratic functions helps develop students' critical and logical thinking skills (Arcavi, 1994). In addition, visual representations such as graphs can make it easier for students to grasp abstract mathematical concepts, provided that teachers scaffold the transition between algebraic and graphical registers (Anthony & Walshaw, 2009; McNeil et al., 2010).

In practice, however, many students find quadratic functions difficult to understand. Reported difficulties include recognizing the general form of the function, interpreting coefficients on a graph, sketching graphs accurately, and solving equations through various algebraic methods (Thurm & Barzel, 2022). These difficulties intensify when students are unable to connect algebraic forms with real-life contexts, leading to rote procedural knowledge that is quickly forgotten (Aydogan Yenmez et al., 2017).

Several studies have attempted to explain why this pattern persists. Pratiwi, Zulaikha, and Hidayat argue that students' low understanding of quadratic functions is a systemic problem, arising not only from the intrinsic complexity of the material but also from instructional approaches that are less contextual and overly focused on the memorization of formulas. Many students are taught to solve problems mechanically without understanding the underlying concepts, while unequal access to qualified teachers, engaging learning media, and technology in some regions further worsens the situation (Boaler, 1998; Amis, 2006). From a broader perspective, López, Robles, and Martínez-Planell describe students' low understanding of quadratic functions as a widespread problem rooted in ineffective, noncontextual teaching approaches across different educational systems (Ydo, 2020).

Most of the studies cited above, however, rely primarily on quantitative achievement data, test scores, or survey instruments to describe the extent of students' difficulties, with comparatively few studies exploring, in depth, how students themselves experience, perceive, and make sense of these difficulties. This leaves a gap in the literature: little is known about the lived, first-person meaning that struggling students attach to their own learning process, and how such meanings might be systematically organized into themes that can inform classroom practice. This gap is even more pronounced in the Indonesian junior secondary context, where qualitative, interpretive studies on quadratic function learning remain scarce, and where the use of AI-assisted qualitative analysis as a transparent, auditable coding aid has rarely been documented.

To help close this gap, the present study adopts a hermeneutic phenomenological approach combined with thematic analysis to explore, in depth, the experiences and perceptions of eighth-grade students regarding their difficulties in learning quadratic functions (Braun & Clarke, 2006; van Manen, 1990). Specifically, this study seeks to answer the following research questions:

a) What categories emerge from the factors that cause students' low understanding of quadratic functions?
b) How do these categories combine to form the main themes underlying students' difficulties in learning quadratic functions?

2. Method

2.1 Research Design

This study employed a hermeneutic phenomenological design (van Manen, 1990; Creswell, 2007). This design was chosen because phenomenology is concerned with the study of phenomena as they are lived and experienced by the individuals involved, in this case, the factors that cause students' low understanding of quadratic function material. The purpose of adopting this design was not only to identify the factors contributing to students' low understanding from a cognitive standpoint, but also to

International Journal of Mathematics and Sciences Education
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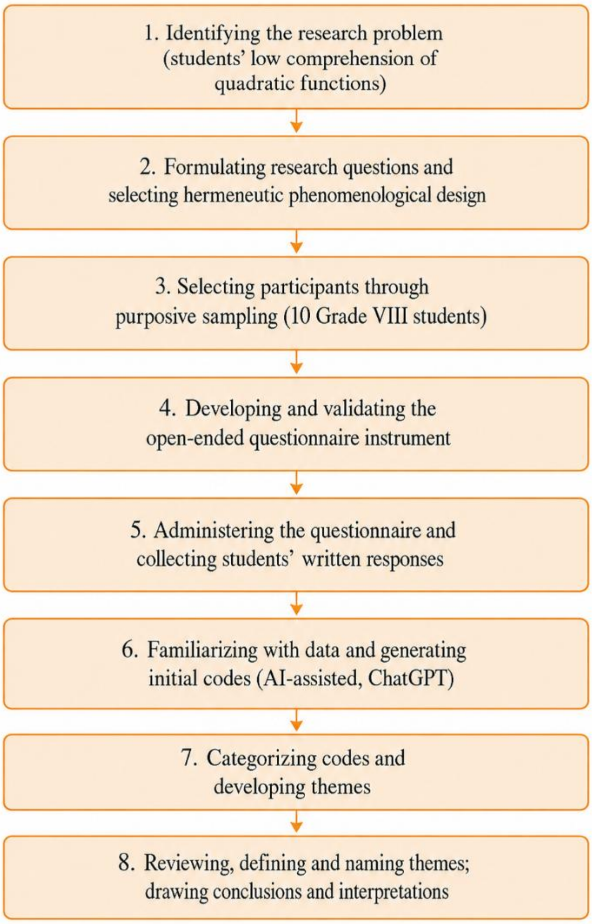
https://nakiscience.com/index.php/IJMSEd

understand these factors from the standpoint of students' own experience, perception, and interpretation of their learning process. The hermeneutic dimension of the design further allowed the researchers to interpret students' written accounts as meaningful texts, moving iteratively between the parts (individual responses) and the whole (emerging themes) to arrive at a coherent understanding of the phenomenon.

The advantage of this design is that it offers a contextual and holistic understanding of the phenomenon under study, rather than reducing students' difficulties to a single numerical score. The overall procedure of the study followed eight sequential stages, from problem identification to the interpretation of findings, as illustrated in Figure 1. This procedural flow was designed to ensure that the interpretive process remained systematic, transparent, and traceable from raw data to final themes, which is particularly important when part of the coding process is supported by an artificial intelligence tool, as described in the Data Analysis section.

Figure 1
Flow of the Research Design



2.2 Research Participants

The participants of this study were 10 eighth-grade students at a public junior high school in West Lombok Regency, Indonesia, selected through purposive sampling. Of the 10 students, 2 were male and 8 were female, with ages ranging from 13 to 15 years. Participants were selected based on the following criteria: (a) currently enrolled in Grade VIII, (b) had received instruction on quadratic functions in the current academic year, and (c) were willing to provide written reflections on their learning experience. The school was chosen because a preliminary observation by the researchers indicated that a considerable number of students in this school experienced low understanding of quadratic function material, making it a relevant site to explore the phenomenon in depth. For confidentiality, participants are referred to in this article using the codes S1 to S10.

International Journal of Mathematics and Sciences Education
Volume 4, Issue 1, pp. 71 – 83
https://nakiscience.com/index.php/IJMSEd

Grade VIII students were specifically selected because, developmentally, students at this age are entering adolescence and are generally considered capable of giving thoughtful, reflective responses to open-ended questions (Steinberg, 2005). Although the sample size of ten participants is small and not intended to be statistically representative, it is consistent with the aims of phenomenological inquiry, which prioritizes depth of understanding of a shared experience over breadth of generalization (Creswell, 2007). Prior to data collection, the purpose of the study was explained to the students and their homeroom teacher, and participation was voluntary; further procedural and ethical details are described in the Ethical Clearance section.

2.3 Data Collection

The instrument used in this study was an open-ended questionnaire designed to explore students' interest in and difficulties with learning mathematics, particularly quadratic functions. The questionnaire consisted of two open-ended questions asking students to describe, in their own words, the factors that caused their low understanding of quadratic function material and to suggest possible solutions or improvements for future learning. Open-ended questions were used to give students the flexibility to express their experiences and perceptions freely, without being constrained by predetermined response categories (Creswell, 2007). The questionnaire items were reviewed for clarity and relevance by the researchers prior to administration to ensure that the wording was accessible to Grade VIII students.

Data collection was carried out in a single session during regular class hours, with the class teacher's permission, and followed the procedure summarized in Table 1. Students completed the questionnaire individually and in writing, with the researchers present to clarify the instructions when needed but without directing the content of the students' answers. The full set of student responses, together with the questionnaire instrument, is documented and retained by the researchers as the primary data source for the subsequent thematic analysis.

Table 1
Data Collection Procedure

Stage	Activity	Time Allocation	Output
1	Introduction and rapport building; explanation of study purpose and voluntary participation	10 minutes	Verbal assent from students
2	Distribution of the open-ended questionnaire and instructions	5 minutes	Questionnaire sheets distributed
3	Independent completion of the questionnaire by students	20 minutes	Written responses (S1–S10)
4	Collection and initial check of completeness of responses	5 minutes	Verified response set
5	Debriefing and closing	5 minutes	Confirmation of data readiness for analysis

2.4 Data Analysis

Data were analyzed using thematic analysis following the six-phase framework of Braun and Clarke (2006): (1) familiarizing oneself with the data, (2) generating initial codes, (3) searching for categories, (4) reviewing and refining themes, (5) defining and naming themes, and (6) producing the report. During the familiarization phase, the researchers repeatedly read the students' written responses to gain an in-depth understanding of the content before coding began. During the initial coding phase, the researchers used ChatGPT as an analytical aid to help generate a first set of candidate codes from the questionnaire transcripts. This AI-assisted output was then treated as a draft only: every candidate code was cross-checked line by line against the original student responses, revised, merged, or discarded by the researchers, and the final coding scheme reflects the researchers' own analytical judgment rather than an unreviewed AI output.

The ten resulting initial codes were then grouped into five categories based on similarity of meaning, and the categories were subsequently condensed into four main themes that best represented the core patterns in the data (see Results). To strengthen the trustworthiness of the analysis, the researchers engaged in investigator triangulation by independently reviewing the coding scheme and discussing discrepancies until consensus was reached, consistent with recommendations for establishing credibility in qualitative research (Creswell, 2007). Confirmability was supported by maintaining an audit trail linking each theme back to its constituent categories, codes, and original student statements, as presented in the Results section.

2.5 Ethical Clearance

This study was conducted in accordance with the ethical principles for research involving human participants, including minors. Prior to data collection, the researchers obtained institutional permission from the school and informed consent from the students' parents/guardians, in addition to verbal assent from the student participants themselves. Participation was voluntary, and students were informed of their right to withdraw at any stage without consequence. All responses were anonymized using participant codes (S1–S10), and data were stored securely and used solely for academic research purposes. Ethical approval for this study was granted by [nama Komite Etik/Institusi Pemberi Persetujuan Etik] under approval number [Nomor Ethical Clearance — mohon dilengkapi].

3. Results

This section presents the findings of the thematic analysis conducted to answer the two research questions: (1) what categories emerge from the factors causing students' low understanding of quadratic functions, and (2) how these categories combine to form the main themes. The presentation moves progressively from the raw initial codes, to categories, to final themes, and is followed by an in-depth narrative account of each theme, illustrated with excerpts from students' own written responses.

Table 2

Initial Codes Derived from Student Responses

No.	Code	Code Description	Illustrative Student Statement (Original Response)
1	K1	Lack of understanding of basic mathematical concepts	"I lack understanding of the basic concepts." (S1)
2	K2	Not understanding the material on quadratic functions	"I do not understand the material on quadratic functions." (S2)
3	K3	Not understanding the material or questions being explained	"I don't understand the material or questions presented." (S3)
4	K4	Difficulty converting a word problem into a quadratic function	"I can't convert the problem into a mathematical sentence (quadratic function)." (S4)

No.	Code	Code Description	Illustrative Student Statement (Original Response)
5	K5	Unable to distinguish between quadratic and linear functions	"I can't tell the difference between a quadratic function and a linear function." (S5)
6	K6	Frequent phone use leading to neglect of study	"I play on my phone so much that I forget to study." (S6)
7	K7	Rarely attending mathematics lessons	"I rarely take math lessons." (S7)
8	K8	Not understanding the teaching methods used by the teacher	"We don't understand the method used in explaining the material, so we don't understand." (S8)
9	K9	Dislike of mathematics lessons	"I don't like math lessons." (S9)
10	K10	Rarely attending lessons and missing material	"I rarely attend lessons, so I miss the material." (S10)

Note. This table presents the initial codes assigned to each student's statement (K1–K10). Coding was used to standardize and simplify the qualitative data by grouping similar responses into concise, comparable units prior to categorization.

The table presents ten initial codes (K1–K10) generated from students' written responses regarding the factors contributing to their low comprehension of quadratic functions. The codes represent several difficulties, including limited conceptual understanding, inability to distinguish quadratic from linear functions, low participation in learning, ineffective teaching methods, and low motivation to learn mathematics. The illustrative student statements provide empirical evidence supporting each code, which subsequently serves as the basis for grouping the codes into broader themes during the thematic analysis.

Table 3

Categories Derived from the Initial Codes

No.	Category	Category Description	Constituent Codes
1	C1	Students' difficulty in understanding the basic concepts and material of quadratic functions	K1, K2, K3
2	C2	Obstacles in applying or distinguishing mathematical forms	K4, K5
3	C3	Discipline problems in studying, such as excessive phone use or absenteeism	K6, K7, K10
4	C4	Lack of effectiveness of the methods used by teachers in explaining the material	K8
5	C5	Dislike of mathematics lessons affecting comprehension	K9

Note. This table condenses the ten initial codes into five broader categories based on the similarity of underlying issues. For example, initial codes related to conceptual understanding (K1, K2, K3) were combined into a single category, helping to reveal general patterns in students' difficulties.

Table 3 presents five categories (C1–C5) developed by grouping the initial codes according to similarities in the problems experienced by students in learning quadratic functions. These categories reflect broader sources of difficulty, including limited conceptual understanding, challenges in applying and distinguishing mathematical forms, learning discipline problems, ineffective teaching methods, and negative attitudes toward mathematics. The categorization provides a more systematic structure for the data and serves as an intermediate analytical stage for developing the broader themes that explain students' low comprehension of quadratic functions.

Table 4

Main Themes Formed from the Categories

No.	Theme Code	Theme Description	Source Categories / Items
1	T1	Difficulty in Understanding Concepts	C1, C2 (Items 1–5: basic-concept confusion; inability to translate problems into quadratic form; inability to distinguish linear from quadratic functions)
2	T2	Lack of Participation in Learning	C3 (Items 6, 7, 10: phone use, absenteeism, missed material)
3	T3	Less Effective Teaching Methods	C4 (Item 8: teaching methods not understood by students)
4	T4	Low Motivation to Learn Mathematics	C5 (Item 9: dislike of mathematics lessons)

Note. This table represents the final stage of thematic condensation, in which categories are consolidated into overarching themes reflecting the core problems students face in learning quadratic functions. For instance, 'Difficulty in Understanding Concepts' emerged as a theme encompassing several categories and initial codes related to conceptual and procedural struggles.

Theme 1: Difficulty in Understanding Concepts

The first and most dominant theme to emerge from the data was difficulty in understanding concepts, encompassing five of the ten initial codes (K1–K5). Students described this difficulty at several interconnected levels: a general lack of grasp of basic mathematical concepts (K1), specific unfamiliarity with quadratic function material (K2), an inability to follow the material or questions being explained in class (K3), difficulty translating a verbal or contextual problem into a quadratic function (K4), and an inability to distinguish a quadratic function from a linear function (K5).

Several students' statements illustrate how this difficulty manifests in concrete classroom situations. One student explained a general sense of not grasping the foundation of the topic ('I lack understanding of the basic concepts,' S1), while another pointed specifically to the quadratic function content itself ('I do not understand the material on quadratic functions,' S2). A more procedural difficulty was voiced by a student who could not represent a word problem symbolically ('I can't convert the problem into a mathematical sentence [quadratic function],' S4), and by another who struggled to differentiate between related but distinct function types ('I can't tell the difference between a quadratic function and a linear function,' S5). Taken together, these statements suggest that students' difficulties are layered: some students struggle at the level of foundational number and algebra sense, while others have grasped isolated procedures but cannot yet integrate them into a coherent conceptual structure for quadratic functions specifically.

This pattern is consistent with the well-documented distinction in the mathematics education literature between procedural and conceptual knowledge (Thurm & Barzel, 2022). Several students appeared able to perform isolated steps — for example, substituting values into a formula — without understanding why those steps apply to a quadratic relationship, echoing findings that students often treat quadratic functions as an arbitrary formula to be memorized rather than as a coherent representation of a relationship between variables (Aydogan Yenmez et al., 2017).

Theme 2: Lack of Participation in Learning

The second theme, lack of participation in learning, was derived from three initial codes (K6, K7, K10) describing behavioral and attendance-related obstacles rather than purely cognitive ones. Students reported that excessive phone use interfered with study time ('I play on my phone so much that I forget to study,' S6), that they rarely attended mathematics lessons ('I rarely take math lessons,' S7), and that infrequent attendance caused them to miss key material ('I rarely attend lessons, so I miss the material,' S10).

These responses point to a behavioral dimension of learning difficulty that is often overlooked when discussing students' understanding of a specific mathematical topic. Because quadratic functions are typically introduced through a sequence of interdependent sub-topics, general form, graph interpretation, and equation-solving, missing even one or two sessions can leave a gap that compounds over subsequent lessons. Students who reported frequent absenteeism or distraction by their phones were, in effect, describing a cumulative deficit: each missed session widened the distance between what was taught and what they were able to follow, which in turn likely reinforced the conceptual difficulties captured in Theme 1.

Theme 3: Less Effective Teaching Methods

The third theme, less effective teaching methods, was derived from a single but recurring code (K8), in which students indicated that they did not understand the method their teacher used to explain the material ('We don't understand the method used in explaining the material, so we don't understand,' S8). Although this theme was represented by only one initial code, it was retained as a distinct theme because it points to a pedagogical, rather than purely cognitive or behavioral, source of difficulty, and because it recurred as a distinguishable concern separate from students' own conceptual struggles.

This finding resonates with the broader literature on differentiated instruction, which argues that a single, uniform teaching method rarely accommodates the diversity of learning preferences within a classroom (Tomlinson, 2001). When quadratic functions, a topic that benefits substantially from multiple representations (symbolic, tabular, and graphical), are taught through a single mode of explanation, students who would otherwise benefit from a visual or concrete approach may be left behind, regardless of their underlying capacity to understand the material.

Theme 4: Low Motivation to Learn Mathematics

The fourth theme, low motivation to learn mathematics, was derived from a single code (K9) reflecting an affective rather than cognitive or behavioral source of difficulty. One student stated simply, 'I don't like math lessons' (S9), a statement that, while brief, signals a broader affective disengagement from the subject that can precede and reinforce the other three themes.

Although represented by a single code, this theme is theoretically significant because affective factors such as interest, confidence, and anxiety are known to mediate how persistently students engage with cognitively demanding topics such as quadratic functions (Anthony & Walshaw, 2009). A student who does not like mathematics lessons is less likely to persist through the layered conceptual difficulties described in Theme 1, less likely to attend consistently as described in Theme 2, and less likely to seek clarification when a teaching method does not suit their learning style, as described in Theme 3.

Integration of the Four Themes

International Journal of Mathematics and Sciences Education
Volume 4, Issue 1, pp. 71 – 83
https://nakiscience.com/index.php/IJMSEd

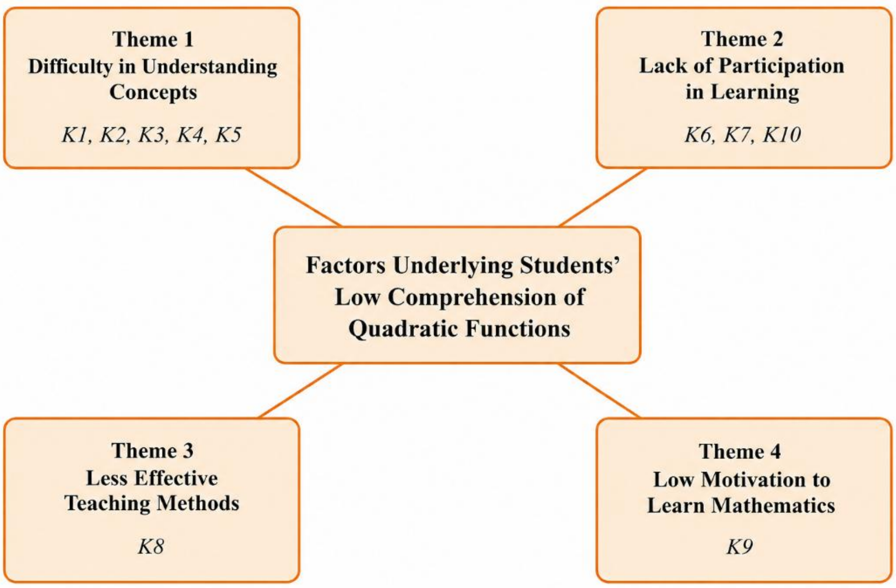
Figure 2 presents a thematic map summarizing how the ten initial codes converge, through five categories, into the four main themes described above. Rather than being independent or mutually exclusive, the four themes appear to interact: cognitive difficulty in understanding concepts (Theme 1) can be intensified by reduced participation (Theme 2), which is itself often driven or accompanied by low motivation (Theme 4), while a teaching method mismatched to students' needs (Theme 3) can simultaneously suppress motivation and widen conceptual gaps. This convergence suggests that students' low comprehension of quadratic functions in this school is best understood not as a single deficit but as a self-reinforcing cycle involving cognitive, behavioral, pedagogical, and affective dimensions, a point that is elaborated further in the Discussion section.

It is also worth noting the relative weight of each theme within the dataset. Theme 1 (difficulty in understanding concepts) was supported by the largest number of initial codes and categories, suggesting that conceptual difficulty was the most consistently reported obstacle among the ten participants. Themes 2, 3, and 4, although each grounded in fewer codes, were not treated as secondary or negligible; rather, their recurrence across independent student responses, combined with their theoretical coherence with established constructs in behavioral, instructional, and motivational theory, supported their retention as distinct themes rather than folding them into Theme 1. This is consistent with thematic analysis guidance that theme prevalence should be judged by its conceptual importance to the research question, not merely by the raw frequency of supporting codes (Braun & Clarke, 2006).

Finally, answering the two research questions directly: with respect to RQ1, the analysis identified five categories underlying students' low understanding of quadratic functions — difficulty with basic concepts and material, obstacles in applying or distinguishing mathematical forms, discipline problems in studying, ineffective teaching methods, and dislike of mathematics lessons. With respect to RQ2, these five categories combined into four overarching themes — difficulty in understanding concepts, lack of participation in learning, less effective teaching methods, and low motivation to learn mathematics — which, taken together, depict students' low comprehension of quadratic functions as a multidimensional and mutually reinforcing phenomenon rather than a single, isolated deficiency.

Figure 2

Thematic Map of Factors Underlying Students' Low Comprehension of Quadratic Functions



4. Discussion

This study set out to explore, through a hermeneutic phenomenological lens, the factors underlying eighth-grade students' low comprehension of quadratic functions and how these factors combine into overarching themes. The findings revealed four interrelated themes, difficulty in understanding concepts, lack of participation in learning, less effective teaching methods, and low motivation to learn mathematics, which together suggest that students' struggles with quadratic functions cannot be reduced to a single cause but instead reflect the interplay of cognitive, behavioral, pedagogical, and affective dimensions of learning.

The dominance of Theme 1 (difficulty in understanding concepts) is consistent with Piaget's account of cognitive development, which suggests that although adolescents in the formal operational stage are capable of abstract reasoning, this capacity still depends on adequate scaffolding through concrete experience and gradual conceptual development. When foundational concepts are not firmly established, students struggle not only with quadratic functions specifically but also with distinguishing related mathematical objects, such as linear and quadratic functions, and with translating real-world problems into symbolic form, precisely the pattern observed among several participants in this study. This reinforces prior findings that procedural fluency without conceptual grounding leaves students unable to flexibly apply quadratic reasoning beyond memorized steps (Thurm & Barzel, 2022; Aydogan Yenmez et al., 2017).

Theme 2 (lack of participation in learning) can be interpreted through a behavioristic lens, in which student engagement is shaped by environmental stimuli and the consequences that follow them (Skinner, 2005). Where lessons fail to offer sufficiently engaging stimuli or meaningful reinforcement, competing stimuli, most notably mobile phone use, as reported by several participants, become more attractive than sustained academic effort. Because quadratic functions are typically taught as a cumulative sequence of sub-skills, even sporadic absenteeism or distraction can produce disproportionately large gaps in understanding, a dynamic that may explain why participation-related difficulties co-occurred so closely with conceptual ones in the present data.

Theme 3 (less effective teaching methods) aligns with differentiated-instruction theory, which holds that students differ in their preferred mode of engaging with content, visual, auditory, or kinesthetic, and that instruction relying predominantly on a single mode, such as lecture-based explanation, risks excluding students whose preferences lie elsewhere (Tomlinson, 2001). Within the context of quadratic functions, a topic that lends itself naturally to multiple representations (algebraic expressions, tables of values, and graphs), an overreliance on verbal or symbolic explanation alone may deprive visually oriented students of the representational bridge they need to construct understanding, consistent with earlier findings on the instructional value of visual representation in mathematics learning (Arcavi, 1994; McNeil et al., 2010).

Theme 4 (low motivation to learn mathematics) reflects affective barriers that are theoretically distinct from, yet closely intertwined with, the preceding three themes. Maslow's hierarchy of needs suggests that higher-order engagement, such as intrinsic interest in a challenging subject, is unlikely to flourish when more basic needs for safety, competence, or a sense of belonging in the classroom remain unmet, while Self-Determination Theory (Deci & Ryan, 1985) similarly emphasizes autonomy, competence, and relatedness as prerequisites for sustained intrinsic motivation. A student who repeatedly experiences failure in understanding basic concepts (Theme 1), who is frequently absent or distracted (Theme 2), and who is taught through methods that do not match their learning style (Theme 3) is, from this theoretical standpoint, unlikely to develop the sense of competence and autonomy that would otherwise sustain motivation to learn mathematics.

Read together, these four themes support the interpretation that students' low comprehension of quadratic functions in this study is not a linear, single-cause problem but rather a self-reinforcing cycle:

conceptual difficulty discourages participation, reduced participation removes opportunities to close conceptual gaps, mismatched teaching methods fail to interrupt this cycle, and the cumulative experience of struggle erodes motivation, which in turn further reduces participation and engagement with the material. This cyclical interpretation extends earlier, more fragmented accounts of quadratic-function difficulties (Boaler, 1998; Ydo, 2020) by showing, through students' own first-person accounts, how cognitive, behavioral, pedagogical, and affective factors are experienced as an interconnected whole rather than as isolated variables.

These findings carry several practical implications for classroom practice. First, because conceptual difficulty was the most prominent theme, teachers may benefit from explicitly scaffolding the transition between concrete, tabular, and graphical representations of quadratic functions before introducing symbolic manipulation. Second, given the salience of participation-related barriers, classroom strategies that actively involve students, such as collaborative problem-solving or brief formative checks, may help re-engage students who would otherwise disengage through absenteeism or distraction. Third, diversifying teaching methods to include visual and hands-on activities may address both the pedagogical and motivational themes simultaneously, since a more varied and participatory classroom experience is likely to be perceived as more enjoyable and relevant by students.

This study is not without limitations. The number of participants (n = 10) and the single-school setting limit the transferability of the findings to other populations, and the reliance on a single open-ended questionnaire, rather than triangulated methods such as interviews or classroom observation, constrains the depth of interpretation that hermeneutic phenomenology ideally affords. In addition, although the initial coding stage was assisted by an AI tool and subsequently verified manually by the researchers, the use of AI in qualitative coding remains a relatively new practice whose long-term implications for interpretive rigor warrant further methodological scrutiny. Future research could address these limitations by incorporating semi-structured interviews or classroom observations, expanding the sample across multiple schools, and evaluating targeted pedagogical interventions designed to interrupt the reinforcing cycle identified in this study.

5. Conclusion

This study explored the factors underlying eighth-grade students' low comprehension of quadratic functions through a hermeneutic phenomenological design combined with thematic analysis. Based on the analysis of open-ended questionnaire responses from ten students, four main themes were identified: (1) difficulty in understanding concepts, (2) lack of participation in learning, (3) less effective teaching methods, and (4) low motivation to learn mathematics. These themes were found to be interrelated rather than independent, forming a self-reinforcing cycle in which cognitive, behavioral, pedagogical, and affective factors jointly shape students' experience of learning quadratic functions. The findings suggest that improving students' understanding of quadratic functions requires more than remedial content instruction; it calls for a more contextual, participatory, and enjoyable learning approach that addresses students' conceptual, behavioral, and affective needs simultaneously. Future intervention studies are recommended to test instructional strategies designed to interrupt this cycle and to examine their effect on students' comprehension of quadratic functions across broader and more diverse school settings.

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Author Contribution

Conceptualization: S.M., E.G.S.; Methodology: S.M., I., M.G.I.; Formal analysis and data curation: S.M., E.G.S.; Investigation: S.M.; Resources: I.; Writing – original draft preparation: S.M.; Writing –

review and editing: E.G.S., I., M.G.I., N.M.A.; Visualization: S.M.; Supervision: I., N.M.A.; Project administration: I. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

AI Declaration

During the data analysis stage of this study, the authors used ChatGPT (OpenAI) as an analytical aid to help generate initial candidate codes from the qualitative questionnaire data. All AI-generated output was subsequently reviewed, verified, corrected, and finalized by the authors, who take full responsibility for the accuracy and interpretation of the reported findings. Generative AI was not used to draft the manuscript's narrative text, to design the study, or to draw its scientific conclusions.

Data Availability

The datasets analyzed in this study, comprising anonymized responses to the open-ended questionnaire, are available from the corresponding author upon reasonable request. Because participants were minors, raw response transcripts are not publicly archived in order to protect participant privacy and confidentiality.

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