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Overview
Обзор

RESEARCH TRENDS AND GAPS IN STUDIES OF ALGEBRAIC EXPRESSIONS IN TÜRKİYE: A SYSTEMATIC REVIEW (2010 – 2025)

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Abstract. This study systematically examined research on algebraic expressions conducted in Türkiye between 2010 and 2025, identifying prevailing trends and gaps in the literature. A total of 190 studies were retrieved from the Web of Science, Scopus, ERIC, DergiPark, and YÖK National Thesis databases for this review. The findings indicate a notable increase in publications after 2016, with a predominant focus on middle school students and qualitative case study designs. Experimental, mixed-method, and meta-analytic studies are scarce. Thematically, the studies mainly addressed achievement and procedural understanding, whereas representational fluency, functional reasoning, and the transition from arithmetic to algebra were largely underexplored topics.

Keywords: mathematics education; algebraic expressions; algebraic thinking; PRISMA; systematic review; content analysis

1. Introduction

Algebra is a core domain of mathematics education and is essential for developing advanced mathematical cognition. It is increasingly conceptualized not merely as symbolic manipulation but as a structural and semiotic system that supports abstraction, generalization, and reasoning (Kaput, 2008; Radford, 2022). Despite this central role, research on algebra in Türkiye is fragmented. Synthesis studies on algebraic expressions and thinking remain limited (e.g., Kaya & Keşan, 2022; Mor, 2021; Özey, 2019; Sibgatullin et al., 2022; Türkoğlu, 2017). This fragmentation has resulted in a lack of a coherent understanding of the thematic, methodological, and epistemic developments in the field. Consequently, there is a need for updated systematic syntheses of the literature. These syntheses should integrate diverse publication types to map research trends and inform future

directions. To address this gap, this study systematically reviews graduate theses and peer-reviewed articles on algebraic expressions in Türkiye between 2010 and 2025.

1.1. Importance of Algebra, Algebraic Thinking, and Algebraic Expressions

Algebra is a fundamental component of mathematics education and a core vehicle for developing mathematical reasoning. It is conceptualized as a symbolic system that represents mathematical relationships. Kieran (1992) described algebra as a representational tool for expressing quantities and relationships using letters and variables, whereas Herbert and Brown (1997) emphasized its role in solving equations, verifying statements, and analyzing functional relationships. Similarly, Moses (1995) characterized algebra as the language of mathematics that enables the construction and communication of mathematical knowledge.

Algebraic thinking is a key construct in mathematics education that is closely associated with higher-order cognition. Herbert and Brown (1997) defined it as the use of symbols, structures, and representations to analyze situations and determine unknowns across multiple representational forms (words, tables, graphs, and equations). Kieran and Chaloug (1993) highlighted its role in developing cognitive schemas through meaningful interpretation of symbols. Kaput (1999) extended this view by emphasizing variables, relational thinking, and representational flexibility, whereas the National Council of Teachers of Mathematics (2000) identified functional reasoning, structural analysis, and quantitative modeling as core components.

Recent research has emphasized structural, semiotic, and sociocultural perspectives on the topic. Radford (2022) frames algebraic thinking as emerging through semiotic mediation and discourse-based meaning-making, whereas Lawrence and Hennessy (2002) stress modeling and prediction in real-world contexts. Collectively, these perspectives position algebraic thinking as central to both mathematical literacy and analytical reasoning.

Furthermore, algebraic thinking develops progressively through the transition from arithmetic to algebra (Kaput, 2008). This transition requires students to move beyond numerical calculations to recognize generalized

relationships, reason with variables, and interpret symbolic representations (Akkan et al., 2012; Kieran & Chalouh, 1993). Rather than using symbols merely as computational tools, students gradually learn to use algebraic expressions to represent mathematical relationships and engage in abstract reasoning (Radford, 2022).

Algebraic expressions form the structural basis of algebra learning; however, research consistently reports students' difficulties with symbolic representation, structural interpretation, and transformation processes (Marpa, 2019; Welder, 2012). These include interpreting symbols, translating word problems, and solving equations (Akkan et al., 2012; Kaya, 2017). Translating verbal situations into algebraic expressions is fundamental to mathematical modelling. It requires students to identify mathematical relationships, represent them symbolically, and reason with unknown quantities (Kieran, 1992). These processes support the transition from concrete, context-dependent reasoning to generalized and abstract algebraic thinking (Herbert & Brown, 1997). These difficulties have been attributed to the abstract nature of algebra, cognitive load, and instruction that emphasizes procedural rather than conceptual understanding (Dede & Argün, 2003; Kaput, 2008). Accordingly, recent studies have emphasized instruction fostering variable reasoning, structural understanding, representational flexibility, and modelling-based learning experiences (Radford, 2022).

1.2. Research Gap, Significance, and Rationale of the Study

Despite algebra's central role in school mathematics, domain-specific syntheses in Türkiye remain limited and fragmented (Mor, 2021; Özey, 2019; Sibgatullin et al., 2022; Türkoğlu, 2017). Existing reviews predominantly address broad, cross-domain mathematics education trends, leaving algebra-specific research comparatively underexplored. Consequently, systematic syntheses of algebraic thinking and expressions are scarce, constraining cumulative knowledge development and obscuring methodological and thematic trends. Contemporary synthesis literature emphasizes that domain-specific reviews are essential for constructing coherent knowledge (Page et al., 2022).

Prior syntheses in Türkiye are largely based on postgraduate theses or cover only restricted time periods. Özey (2019) identified a dominance of studies on algebraic expressions (2010–2018) with a methodological preference for qualitative, quantitative, case, and experimental designs, often emphasizing achievement rather than conceptual understanding. Similarly, Mor (2021), in an analysis of 156 articles (1995–2021), reported persistent difficulties in equality and equation concepts, alongside teachers' challenges in addressing these misconceptions. Türkoğlu (2017) highlighted early algebraic reasoning and pattern recognition but noted limitations stemming from heterogeneous and restricted datasets.

Although a broader body of research has examined curricula and textbooks (Yenilmez & Teke, 2008), misconceptions (Dede & Argün, 2003; Welder, 2012), instructional interventions (Birgin & Demirören, 2025; Kabadaş & Mumcu, 2022), arithmetic-to-algebra transitions (Akkan et al., 2012; Bağdat & Saban, 2014; Kabadaş & Mumcu, 2022), and achievement outcomes (Birgin & Demirören, 2020; Kaya, 2017), few synthesis studies have examined students' progression from arithmetic reasoning to abstract algebraic thinking. Mathematical modelling and the translation of word problems into algebraic expressions also remain underrepresented, limiting a comprehensive understanding of research trends. Consequently, the literature remains thematically dispersed and methodologically inconsistent, limiting comprehensive and integrative interpretations of research trends in this area.

Despite the expansion of research in this field, an integrated synthesis of graduate theses and peer-reviewed studies indexed in Scopus, ERIC, and Web of Science (WoS) is still lacking in the literature. This gap limits a comprehensive understanding of the methodological trends, thematic distributions, and emerging priorities in algebra education in Türkiye. Research synthesis literature further underscores that integrating multiple publication types enhances the robustness and generalizability of findings.

Accordingly, this study presents an updated systematic review of research on algebraic expressions in Türkiye (2010 – 2025), integrating findings from theses and peer-reviewed articles. It provides a coherent account of the field by identifying dominant themes, methodological trends, and underexplored

areas, thereby contributing to an evidence-based agenda. In addition, the review identifies important gaps in research on algebraic thinking, particularly regarding the transition from arithmetic to algebra, symbolic representation, and mathematical modelling, and outlines directions for future studies. Specifically, this study aims to identify research trends and propose future directions for research on algebraic expressions in Türkiye during this period by addressing the following research questions:

a) What trends can be observed in studies on algebraic expressions by publication type and year, and what might explain these trends?
b) What methodological patterns emerge in terms of research methods, designs, samples, data collection tools, and analysis techniques, and what might explain these patterns?
c) What trends are evident in terms of mathematics content and research focus, and how can these trends be interpreted?

2. Method

2.1. *Research Model*

This study systematically reviewed research on algebraic expressions in Türkiye (2010–2025) using document analysis methodology. Postgraduate theses and peer-reviewed journal articles were included in this study. Document analysis enables the identification of patterns, themes, and methodological characteristics across studies (Miles & Huberman, 1994). This study was designed as a descriptive, systematic review.

2.2. *Research Sample and Data Collection*

The dataset comprised master's theses, doctoral dissertations, and peer-reviewed articles on algebraic expressions published in Türkiye between 2010 and 2025. A comprehensive search was conducted in the YÖK National Thesis Center, Web of Science, Scopus, ERIC, and DergiPark using the keywords "algebraic expressions," "algebra," "algebraic thinking," and "Türkiye OR Turkey" in the titles, abstracts, and keywords.

The initial search yielded 116 theses (YÖK), 63 articles (DergiPark), 11 records (ERIC), 46 records (Scopus), and 14 records (Web of Science [WoS]). This review followed the PRISMA 2020 guidelines (Page et al., 2022) to ensure transparent identification, screening, and selection (Figure 1). The

inclusion criteria were as follows: (a) publication between 2010 and 2025, (b) focus on algebraic expressions in mathematics education, and (c) studies conducted in Türkiye. Studies outside mathematics education, inaccessible full texts, and restricted theses were excluded.

After screening, 12 YÖK theses were excluded (3 inaccessible, 9 irrelevant), and 36 DergiPark articles were excluded (12 duplicates, 9 irrelevant, 15 off-topic), leaving 27 articles. Three studies (two non-Turkish and one book chapter) were excluded from ERIC. From Scopus, 13 studies were excluded (5 duplicates, 8 non-Turkish), leaving 33 studies. One WoS study was excluded, leaving 13 studies. The final dataset comprised 190 studies, including 77 journal articles, 95 master's theses and 18 doctoral dissertations.

2.3. *Data analysis*

The framework is based on theoretical perspectives, including algebraic thinking, representational fluency, and the transition from arithmetic to algebra. These constructs were operationalized into analyzable dimensions. The framework draws on previous systematic reviews in mathematics education (e.g., Kaya & Keşan, 2022; Özey, 2019; Sibgatullin et al., 2022), ensuring methodological rigor and comparability (Saldaña, 2016).

The framework included descriptive and thematic data categories. The descriptive categories included publication year, publication type, research design, participants, data collection tools, and data analysis methods. Thematic categories captured the mathematical content focus (e.g., expressions, equations, functions) and research orientation (conceptual vs. procedural emphasis, representational use), reflecting the key dimensions of algebraic thinking. These categories were used to identify methodological trends and thematic orientations.

The analysis was conducted in two stages. First, the studies were coded according to the predefined categories. Second, we identified emerging themes through iterative qualitative coding. Content analysis refers to a systematic procedure for coding, categorizing, and interpreting document-based data (Creswell & Creswell, 2017). The coding scheme was iteratively refined to enhance its conceptual coherence and internal consistency.

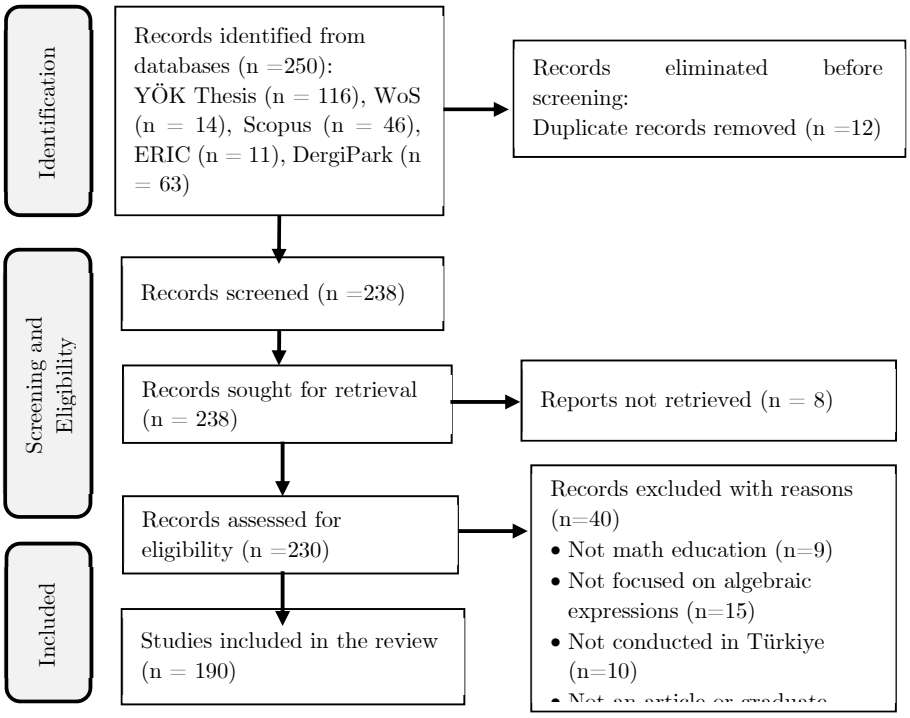


Figure 1. PRISMA 2020 flow diagram of the study selection process for research on algebraic expressions in Türkiye

To ensure reliability, 50 studies (26.3%) were independently coded by two research assistants. Intercoder agreement was calculated using Miles and Huberman's (1994) formula, which yielded an agreement of 92.6%. Additionally, Cohen's Kappa was $\kappa = .89$, indicating almost perfect agreement (Landis & Koch, 1977). These results confirm the robustness of the proposed coding framework. Following the establishment of reliability, the remaining studies were coded using the finalized scheme. Discrepancies were resolved by consensus (Saldaña, 2016). Finally, the coded data were summarized using descriptive statistics and presented in the form of tables and figures.

3. Findings

3.1. Distribution of studies by year and publication type

The distribution of studies by publication type and year is shown in Table 1. Of the 190 studies, 50% (f = 95) were master's theses, 40.5% (f = 77) were journal articles, and 9.5% (f = 18) were doctoral dissertations, indicating a dominance of master's-level research and limited doctoral output in this field. Temporal trends revealed a growth phase between 2016 and 2023, with a peak in 2019 (f = 28) followed by a decline in the later years of the period.

Table 1. Distribution of studies on algebraic expressions by publication year

Year	Article	Master's Thesis	Doctoral Dissertation	Total
2010	3	4	0	7
2011	4	4	1	9
2012	1	5	2	8
2013	2	3	1	6
2014	3	2	0	5
2015	1	2	1	4
2016	3	6	2	11
2017	8	6	1	15
2018	5	12	1	18
2019	6	21	1	28
2020	9	5	2	16
2021	11	5	2	18
2022	2	7	0	9
2023	12	9	1	22
2024	4	2	2	8
2025	3	2	1	6
Total	77(40.5%)	95 (50.0%)	18 (9.5%)	190 (100%)

3.2. Distribution of studies by research method and design

As shown in Table 2, qualitative methods (44.7%, f = 85) were the most prevalent, followed by quantitative methods (35.8%, f = 68) and mixed methods (19.5%, f = 37). This indicates a general preference for qualitative

approaches in research on algebraic expressions. Table 3 shows that case study (f = 55), experimental design (f = 48), and survey design (f = 30) were the most frequently used research designs in the field. Other designs, including teaching experiments, document and content analyses, action research, phenomenology, and mixed-method designs, were used less frequently, indicating methodological diversity but limited use of advanced mixed-method designs.

3.3. Distribution of studies by study group and sample size

As shown in Table 4, most studies focused on middle school students (f = 120), followed by pre-service teachers (f = 24), middle school teachers (f = 19), and high school students (f = 11). Other groups were rarely represented in the literature. This indicates a strong concentration at the middle school level, which is consistent with the introduction of algebra into the curriculum.

Table 2. Distribution of studies on algebraic expressions by research method

Research method	***f***	*%*
Quantitative	68	35.8
Qualitative	85	44.7
Mixed methods	37	19.5
Total	190	100

Table 3. Distribution of studies on algebraic expressions by research design

Research design	***f***	*%*	**Research design**	***f***	*%*
Case study	55	28.9	Descriptive survey	4	2.1
Experimental	48	25.2	Action research	5	2.6
Survey	30	15.8	Theoretical study	4	2.1
Teaching experiment	13	6.8	Document analysis	7	3.7
Content analysis	6	3.2	Explanatory sequential mixed design	3	1.6
Phenomenology	5	2.6	Convergent parallel mixed design	3	1.6
Relational survey	5	2.6	Explanatory mixed design	2	1.2

Note. Multiple codes were applied.

Regarding sample size, studies were distributed relatively evenly across categories, with 41–100 participants (26.9%) and 11 – 40 participants (23.2%) being the most common, followed by larger and smaller samples. Overall, the findings indicate methodological variability in sample size selection.

Table 4. Distribution of studies by study group and sample size

Study group	***f***	***%***	**Sample size**	***f***	***%***
Preschool Students	1	0.6	1-10	29	15.2
Elementary School Students	2	1.2	11-40	44	23.2
Middle School Students	120	67.0	41-100	51	26.9
High School Students	11	6.1	More than 100	36	18.9
Pre-Service Math Teachers	24	13.4	No sample	30	15.8
Classroom Teachers	1	0.6			
Middle School Math Teachers	19	10.5			
High School Math Teachers	1	0.6			

3.4. Distribution of studies by data collection tools and data analysis methods

Figure 2 shows that achievement tests (47%) and interviews (36.6%) were the dominant data collection tools, followed by surveys/scales (19%), document analysis (19%), and observation (15.9%). This reflects a strong reliance on performance-based and qualitative elicitation tools.

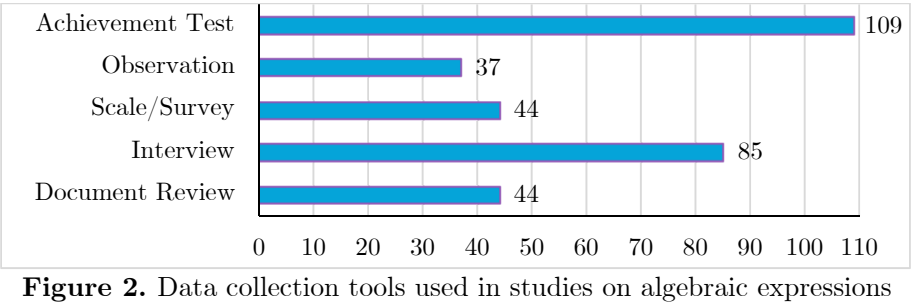


Figure 2. Data collection tools used in studies on algebraic expressions

The distribution of studies according to data analysis methods is presented in Table 5. Quantitative analyses were predominantly based on t-tests (27.4%; f = 52) and descriptive statistics (22.6%; f = 43), followed by

Mann–Whitney U (10.0%; f = 19), ANOVA (6.8%; f = 13), Wilcoxon signed-rank test (5.3%; f = 10), and correlation analysis (4.7%; f = 9). For qualitative approaches, content analysis was the most prevalent (36.3%; f = 69), followed by descriptive (21.6%; f = 41) and document analyses (13.7%; f = 26).

Table 5. Data analysis methods used in studies on algebraic expressions

Quantitative data analysis	***f***	***%***	**Qualitative data analysis**	***f***	***%***
Descriptive statistics	43	22.6	Descriptive analysis	41	21.6
t-test	52	27.4	Content analysis	69	36.3
ANOVA	13	6.8	Document analysis	26	13.7
Mann-Whitney U	19	10.0			
Wilcoxon signed ranks	10	5.3			
Correlation	9	4.7			
Shapiro-Wilk	6	3.2			
Regression	5	2.6			
Factor analysis	2	1.1			
Kolmogorov–Smirnov	1	0.5			

Note. Multiple codes were applied because some studies addressed more than one theme.

3.5. Distribution of studies on algebraic expressions by mathematical topics

Table 6. Distribution of studies on algebraic expressions by mathematical topics

Mathematics subjects	***f***	***%***
Algebraic expressions	107	56.3
Equations	44	23.2
Pattern and relationships	25	13.2
Linear equations and graphs	10	5.2
Quadratic equations	4	2.1

The distribution of studies by mathematics subject is shown in Table 6. Most studies focused on algebraic expressions (56.3%, f = 107), followed by equations (23.2%, f = 44), and patterns and relationships (13.2%, f = 25).

In contrast, relatively few studies addressed linear equations and graphs (5.2%, f = 10) and quadratic equations (2.1%, f = 4), indicating a focus on foundational algebra topics.

3.6. Distribution of Studies on Algebraic Expressions by Their Purpose

Table 7 shows the distribution of studies on algebraic expressions according to their research focus.

Table 7. Distribution of studies on algebraic expressions by research focus

Research focus	***f***	***%***
Effects of instructional approaches on algebra achievement	64	33.7
Computer-assisted instruction	18	9.5
Instruction using concrete materials	16	8.4
Instruction using virtual manipulatives	12	6.3
Game-based instruction	11	5.8
Problem-based instruction	7	3.7
Algebraic reasoning and conceptual understanding	47	24.7
Levels of algebraic thinking	29	15.3
Concept images of algebraic expressions	10	5.3
Problem-solving and problem-posing in algebra	5	2.6
Algebraic thinking processes and attitudes	3	1.6
Students' algebra learning processes	35	18.4
Achievement outcomes	17	8.9
Misconceptions and errors	13	6.8
Attitudes towards algebra	5	2.6
Teachers' views and pedagogical content knowledge	22	11.6
Pre-service teachers' views and knowledge	12	6.3
In-service teachers' views and knowledge	7	3.7
Teacher-led exploratory studies	3	1.6
Document-based review studies on algebra learning	16	8.4
Theses and journal articles	5	2.6
Curricular documents	7	3.7
Textbooks	4	2.1
Transition from arithmetic to algebra and related approaches	6	3.2
Teachers' instructional approaches	3	1.6
Students' achievement comparisons	2	1.1
Implementation of algebraic activities	1	0.5

Most studies are focused on examining the effects of instructional approaches on algebra achievement (33.7%, f = 64), including computer-assisted (f = 18), concrete materials-based (f = 16), virtual manipulatives (f = 12), game-based (f = 11), and problem-based instruction (f = 7).

Another group focused on students' algebraic reasoning and conceptual understanding (24.7%, f = 47), particularly algebraic thinking levels (f = 29), concept images (f = 10), problem-solving and problem-posing skills (f = 5), and thinking processes/attitudes (f = 3).

Studies on students' algebraic learning processes (18.4%, f = 35) examined achievement outcomes (f = 17), misconceptions and errors (f = 13), and attitudes toward algebra (f = 5). Research on teachers' views and pedagogical content knowledge (11.6%, f = 22) included pre-service (f = 12), in-service (f = 7), and teacher-led studies (f = 3).

Document-based review studies (8.4%, f = 16) analyzed theses and journal articles (f = 5), curricula (f = 7), and textbooks (f = 4), emphasizing evidence synthesis rather than classroom-based inquiries. Finally, studies on the transition from arithmetic to algebra (3.2%, f = 6) addressed instructional practices (f = 3), achievement comparisons (f = 2), and activity implementation (f = 1).

Overall, research in Türkiye has predominantly emphasized instructional practices and students' conceptual development, while teacher cognition, document-based analyses, and arithmetic-to-algebra transition studies remain underrepresented.

4. Discussion and Conclusions

In this study, a systematic review of 190 studies on algebraic expressions in Türkiye (2010 – 2025) was conducted to identify research trends, methodological characteristics and research gaps. Temporal analysis revealed a non-linear pattern: low production (2010 – 2015), a marked increase (2016 – 2019), a peak in 2019, and a decline in the later years of the period. This trajectory likely reflects the combined influence of the 2018 curriculum reform, which emphasized constructivist approaches (Kaya & Keşan, 2022), and the disruptions associated with the COVID-19 pandemic. These findings align with prior reviews (Mor, 2021; Özey, 2019) and indicate

that policy shifts and contextual factors significantly shape research productivity and orientation.

Most studies were master's theses or journal articles, while doctoral dissertations were relatively few. This structural imbalance suggests constraints on the production of large-scale, longitudinal, and methodologically complex studies in this field. Consistent with earlier studies (Özey, 2019; Türkoğlu, 2017), this pattern highlights the need to strengthen doctoral-level research capacity to enhance methodological depth and analytical scope.

Methodologically, qualitative designs predominated, followed by quantitative and mixed-method approaches. This aligns with the findings of Sibgatullin et al. (2022) and reflects a broader interpretive orientation in mathematics education research. However, the dominance of qualitative approaches may also reflect small-scale datasets and an exploratory research culture focused on reasoning and misconceptions rather than generalization. The limited use of certain designs (e.g., explanatory mixed methods, theoretical frameworks, convergent designs) indicates insufficient methodological diversification.

Similarly, achievement tests and interviews are the most frequently used instruments (Sibgatullin et al., 2022). The limited adoption of diverse data sources suggests the need for a broader methodological approach. Future research should integrate multimodal designs and richer datasets to enhance explanatory and inferential strengths.

Most studies focused on middle school students, followed by pre-service and in-service teacher education. This distribution is consistent with Özey (2019) and reflects the curricular introduction of algebra at this level. However, high school contexts and practicing teachers remain underexplored, limiting insights into advanced algebraic reasoning and instructional continuity across grades.

Regarding data analysis, qualitative studies relied mainly on content and descriptive analyses, while quantitative studies primarily used descriptive statistics and t-tests, with limited application of advanced methods (e.g., ANOVA, regression, and factor analysis). This mirrors previous findings

(Sibgatullin et al., 2022; Türkoğlu, 2017) and indicates restricted analytical sophistication in quantitative research.

Although algebraic expressions dominate the literature (Kaya & Keşan, 2022; Özey, 2019), related subdomains such as equations, functions, patterns, and quadratic structures are comparatively underrepresented. While this reflects curricular emphasis, it also signals a narrow conceptual focus that limits broader interpretations of algebraic thinking.

In terms of research focus, most studies have examined student-centered instruction and conceptual learning, along with reasoning processes and teachers' pedagogical knowledge (Mor, 2021; Özey, 2019; Türkoğlu, 2017). However, studies on textbooks, teachers' perspectives, and arithmetic-to-algebra transition remain limited, and no meta-analytic or bibliometric studies have been identified to date. Similarly, relatively few studies have examined students' progression from arithmetic reasoning to abstract algebraic thinking through symbolic representation and the translation of word problems into algebraic expressions. Mathematical modelling also remains an underexplored area in the literature. This suggests an imbalance between the cognitive/instructional perspectives and systemic or curricular analyses.

From an international perspective, the dominance of qualitative and small-scale studies aligns with global trends in mathematics education. However, the absence of large-scale synthesis approaches (e.g., meta-analysis, bibliometrics) distinguishes Türkiye from more mature research systems, where cumulative knowledge building is more advanced.

Overall, although algebraic expression research in Türkiye is substantial and curriculum-aligned, it remains methodologically constrained and thematically imbalanced in scope. Strengthening methodological rigor, expanding participant diversity, and integrating advanced analytical and synthesis approaches are essential for enhancing the analytical depth and international visibility of this field. Greater attention should also be devoted to research on arithmetic-to-algebra transition, symbolic representation, and mathematical modelling, given their fundamental roles in fostering students' abstract algebraic thinking.

5. Limitations and Future Research Directions

This study had several limitations. First, the inclusion of only full-text accessible studies may have excluded relevant grey literature (e.g., conference proceedings and institutional reports), thereby limiting comprehensiveness. Second, the exclusion of non-indexed local studies may have affected representativeness. Third, the observed methodological and thematic concentration constrains the breadth of interpretive generalization.

Future research should broaden database coverage and systematically incorporate gray literature to enhance the comprehensiveness of the results. Bibliometric and meta-analytic approaches are recommended to identify influential studies, structural patterns, and cumulative research trends. Methodological diversification is also required, particularly through experimental, longitudinal, action research, and mixed-method designs supported by advanced statistical techniques (e.g., regression, SEM, and factor analysis).

In addition, the participant samples should be diversified to include high school students and in-service teachers to better capture the developmental trajectories of algebraic thinking. Finally, underexplored areas such as equations, functions, textbook analysis, teacher cognition, and arithmetic-to-algebra transition should be prioritized in future research. Future studies should focus on students' development of abstract algebraic thinking through symbolic representation, translating word problems into algebraic expressions, and mathematical modelling to inform conceptually oriented instructional practices to this end. Addressing these gaps is essential for enhancing the methodological rigor, analytical depth, and international visibility of algebra education research in Türkiye.

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