

Vedic and Conventional Methods of Mathematical Calculation and Problem Solving: A Review of the Literature

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Abstract. Vedic Mathematics, a system of sixteen sutras and thirteen sub-sutras popularised from the mid-twentieth century, is widely promoted as a faster and more intuitive alternative to the standard written algorithms taught in schools. This article reviews the literature on the subject, drawing on sixteen core studies and twenty-nine supplementary historical, theoretical and methodological sources. It sets out the conceptual and historical background, including the contested question of the origin of the sutras; examines the learning theories invoked to explain the effects of alternative calculation strategies; and synthesises empirical and conceptual work on calculation speed and accuracy, problem solving, mathematical achievement and affective outcomes, together with applications in arithmetic, algebra, geometry, engineering and teacher education. The studies reviewed point in a consistently favourable direction: learners taught Vedic techniques generally perform well on the tasks involved, often more quickly and accurately than with conventional procedures, and report positive attitudes. However, the evidence base is limited by small samples, short interventions, heterogeneous designs, researcher-made instruments, and a reliance on tasks closely aligned with the taught methods. Mathematics anxiety, long-term retention and transfer to non-routine problems have been little examined. The article concludes that Vedic Mathematics is best regarded as a promising but provisional set of alternative strategies, and identifies the need for focused, controlled comparisons that measure speed, accuracy, problem solving and achievement together.

Keywords: *Vedic Mathematics; conventional methods; calculation speed; problem solving; mathematical achievement; mathematics education; literature review*

1. Introduction

Arithmetic calculation remains a foundation of school mathematics, yet the written algorithms through which it is usually taught place sustained demands on learners. Multi-step procedures for multiplication, division and root extraction require intermediate results to be held in memory while further steps are carried out, and errors frequently arise from this load. Against this background, Vedic Mathematics has attracted considerable attention in India and abroad as a body of alternative calculation strategies said to be shorter, more intuitive and often more accurate than standard procedures [18], [5]. Whether these claims hold up under educational evaluation is an empirical question, and one on which the literature is growing but uneven.

The purpose of this review is not merely to list earlier studies but to locate research on Vedic and conventional methods within an existing body of knowledge, to clarify the concepts on which it rests, to identify the methods and findings of earlier researchers, and to show where questions remain unanswered. Studies are organised thematically rather than chronologically so that findings on the same construct can be read against one another. The review addresses five questions: (i) what Vedic Mathematics is and how its origin is understood; (ii) which theories explain why alternative calculation strategies might influence learning; (iii) what the empirical evidence shows for speed, accuracy, problem solving, achievement and attitudes; (iv) in which mathematical and computational domains the techniques have been applied; and (v) how reliable the evidence is and what remains to be studied.

The review draws on journal articles, conference and review papers, and scholarly books. Numbered citations in square brackets refer to the reference list at the end of the article. Sources [1] to [16] constitute the core body of Vedic Mathematics research reviewed, together with the empirical study [17], while [18] to [45] comprise the supplementary historical, theoretical and methodological sources used to interpret that research.

2. Conceptual and Historical Background

2.1 Origin and popularisation

The term Vedic Mathematics is most closely associated with Jagadguru Swami Sri Bharati Krishna Tirthaji Maharaja (1884–1960), Shankaracharya of the Govardhana Matha at Puri, whose book Vedic Mathematics was published posthumously in 1965 under the editorship of V. S. Agrawala [18]. Tirthaji presented sixteen sutras (aphorisms) and

thirteen sub-sutras (corollaries) which, in his account, provide a unified and economical means of performing arithmetic, algebraic, geometric and calculus-related operations. The central claim is that a small number of general principles can generate a large number of specific procedures, and that these are often shorter and more intuitive than the standard school algorithms.

Since its publication the system has been popularised through textbooks, workshops, coaching programmes and online materials. Eswaran and Singaravelu describe it as a unified and interconnected framework that supports mental computation, flexible solution methods and creativity [5]; Dixit emphasises its roots in Indian mathematical traditions together with contemporary educational applications [4]; and Shekhar explores the sutras and sub-sutras and their use across arithmetic, algebra, geometry and calculus [14]. This descriptive literature largely shapes how teachers and learners understand Vedic Mathematics today: as a set of named techniques, each linked to a Sanskrit aphorism and each suited to particular kinds of numbers or expressions.

2.2 The sutras and their algebraic basis

The sixteen sutras are usually cited with brief English renderings describing the operation to be carried out. Table 1 summarises how they are commonly presented in the popular and educational literature [9], [14]; it is not an endorsement of any particular interpretation.

Table 1. The sixteen sutras of Vedic Mathematics as commonly presented

No.	Sutra	Commonly given meaning	Typical area of use
1	Ekadhikena Purvena	By one more than the previous one	Squares of numbers ending in 5; recurring decimals
2	Nikhilam Navatashcaramam Dashatah	All from 9 and the last from 10	Multiplication and division near a base
3	Urdhva-Tiryagbhyam	Vertically and crosswise	General multiplication; polynomial products
4	Paravartya Yojayet	Transpose and adjust	Division; linear equations
5	Shunyam Samyasamuccaye	When the sum is the same, that sum is zero	Simple and special equations
6	(Anurupye) Shunyamanyat	If one is in ratio, the other is zero	Simultaneous linear equations
7	Sankalana-Vyavakalanabhyam	By addition and by subtraction	Simultaneous equations
8	Puranapuranabhyam	By completion or non-completion	Completing the square; polynomials
9	Chalana-Kalanabhyam	Differences and similarities	Quadratic and higher-degree equations
10	Yavadunam	Whatever the extent of its deficiency	Squaring and cubing
11	Vyashtisamanstih	Part and whole	Algebraic factorisation
12	Shesanyankena Charamena	The remainders by the last digit	Divisibility; recurring decimals
13	Sopantyadvayamantyam	The ultimate and twice the penultimate	Special rational equations
14	Ekanyunena Purvena	By one less than the previous one	Multiplying by numbers consisting of 9s
15	Gunitasamuchyah	The product of the sum is the sum of the products	Verifying products and factors
16	Gunakasamuchyah	The factors of the sum are the sum of the factors	Factorisation; verification

Three sutras recur in the empirical studies. Nikhilam Navatashcaramam Dashatah multiplies numbers close to a power of ten by working with their deficiencies from the base. To compute 97×94 , subtract each number from 100 to obtain the deficiencies 3 and 6; the cross-difference $97 - 6$ (or $94 - 3$) gives 91, and the product of the deficiencies, $3 \times 6 = 18$, gives the answer 9118. Urdhva-Tiryagbhyam, vertical and crosswise multiplication, combines partial products column by column: in 23×14 , the left digits give $2 \times 1 = 2$, the cross products give $2 \times 4 + 3 \times 1 = 11$, and the right digits give $3 \times 4 = 12$, which combine with carrying to yield 322. Ekadhikena Purvena, applied to squaring numbers ending in 5, multiplies the preceding digit(s) by the next higher integer and appends 25, so that 35^2 is (3×4) followed by 25, that is 1225.

Each procedure follows from ordinary algebraic identities. The Nikhilam method for 97×94 rests on $(b - x)(b - y) = b(b - x - y) + xy$ with $b = 100$. This matters because several authors argue that the techniques possess an organised algebraic basis and should not be dismissed as isolated tricks [9]. It also means that whether the techniques are taught with their justification or merely as steps to be memorised may affect their educational value, a point taken up in Section 3.

2.3 Critical and historiographical perspectives

The literature is not uniformly favourable, and a responsible review must note the debate about provenance. Tirthaji stated that he had reconstructed the sutras from the Atharvaveda, but they have not been located in the known Vedic texts, a point acknowledged even in the foreword to the original edition [18]. Historians of Indian mathematics therefore distinguish between the genuine achievements of ancient and classical Indian mathematics, such as the decimal place-value system, the work of Aryabhata, Brahmagupta and Bhaskara, and the Kerala school, and the particular system presented in Tirthaji's book [19], [20], [22]. Dani argues that claims of Vedic origin are not supported by textual evidence while acknowledging that many of the devices are mathematically interesting and may have pedagogical value [19]. Plofker situates Indian mathematical thought in documented texts and traditions [20], and Joseph emphasises the contribution of Indian mathematicians to number systems and algebra [22].

The debate is relevant here for two reasons. First, the educational evaluation of Vedic Mathematics does not depend on resolving the question of its antiquity: a calculation strategy can be assessed for speed, accuracy and contribution to understanding irrespective of its attribution. Second, it explains why Khatri [9] and others have defended the systematic, algebraic character of the methods against the view that they are only a bag of tricks. Contemporary educational studies generally treat Vedic Mathematics as a set of alternative computational strategies whose classroom effectiveness is an empirical matter.

3. Theoretical Perspectives on Learning Alternative Calculation Methods

Researchers who explain why Vedic methods might influence learning draw on several established theories, which provide the interpretive lens for the empirical findings reviewed later.

3.1 Cognitive load theory

Cognitive load theory holds that working memory is limited in capacity and duration, and that instruction is effective to the extent that it avoids unnecessary demands on it [30]. Written algorithms for multiplication, division or root extraction require learners to hold intermediate results while carrying out further steps. Many Vedic techniques reduce the number of intermediate quantities by working left to right, by operating on deficiencies rather than large numbers, or by reducing a calculation to a single line. Pimpalkar argues that such simplification may lower extraneous load, but notes that empirical testing of structured learning packages is limited [11]. The claim is plausible yet largely theoretical, and Vedic techniques can introduce their own load, since learners must recognise which technique suits which numbers and remember a larger repertoire of procedures.

3.2 Constructivist and sociocultural theories

Constructivist theories view learners as active builders of knowledge. Where Vedic Mathematics is taught as a family of related strategies from which students choose according to the structure of a problem, it can encourage flexible and inventive thinking [5], [11]. Bruner's emphasis on discovery and the structure of a discipline [38] and Vygotsky's account of socially mediated learning [36] are commonly cited in this context. The practical implication is that the same techniques may have different effects depending on whether they are presented as ready-made rules or discovered and justified through class discussion.

3.3 Dual coding and metacognition

Dual coding theory proposes that information encoded verbally and visually is better remembered than information encoded in one form only [40], a view supported by research on multimedia learning [39]. Several Vedic procedures, such as the vertical-and-crosswise pattern and base-and-deficiency diagrams, are strongly spatial, and Pimpalkar draws on dual coding to explain their usefulness [11]. Metacognition, the awareness and regulation of one's own thinking [28], is also relevant: choosing among methods requires learners to monitor a problem, judge which strategy fits and check the result, and the availability of several valid routes allows verification by a second method.

3.4 Conceptual and procedural knowledge

Mathematics education distinguishes conceptual knowledge, the understood relationships among ideas, from procedural knowledge, the rules and steps for carrying out tasks [27]. Skemp's parallel distinction is between relational understanding (knowing what to do and why) and instrumental understanding (rules without reasons) [26]. The two kinds of knowledge appear to develop iteratively and to support one another [34], and national syntheses identify conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition as intertwined strands of proficiency [29]. For Vedic Mathematics the implication is clear: if techniques are taught only as tricks they risk promoting purely instrumental understanding, whereas teaching them with their algebraic justification may build both fluency and understanding, the second path being the one Khatri argues is available [9].

3.5 Number sense, mental computation and problem solving

Number sense denotes a flexible understanding of numbers, their magnitudes and their relationships [37], [41]. Proficient calculators use strategies adapted to the numbers at hand rather than a single fixed algorithm [31], [32]; Sowder noted that such flexibility depends on instruction that values alternative methods [31], and Threlfall argued that it is better understood as noticing features of particular numbers than as possessing a list of strategies [32]. Vedic Mathematics fits this perspective closely because many sutras are explicitly conditional: Nikhilam works best near a base, and Ekadhikena Purvena for numbers ending in 5. Choosing between them demands the kind of attention that the number sense literature seeks to develop [5].

Polya's four phases of problem solving (understand, plan, carry out, look back) remain a basic reference [25], and Schoenfeld showed that success depends on knowledge, heuristics, control and beliefs [33]. Calculation fluency can free attention for planning and monitoring; laborious calculation can consume the resources needed for strategy selection. This is the logic implicit in studies that treat computational efficiency as a route to improved problem solving [2].

3.6 Implications

Read together, these perspectives generate testable expectations: fewer sequential steps should reduce errors and completion time (cognitive load); outcomes should depend on how the methods are taught (constructivism); gains in fluency should be more durable when accompanied by understanding (conceptual–procedural); and benefits should be greatest where learners choose methods by the properties of the numbers (number sense). They also warn that a single comparison of Vedic and conventional scores, without information on how each method was taught and practised, can be interpreted in more than one way. A sound comparison must define its tasks clearly, equate instruction, and measure more than one outcome.

4. Empirical Evidence on Vedic and Conventional Methods

4.1 General and comparative studies

Conventional methods here refer to the standard written algorithms taught in schools, such as column addition and subtraction with carrying and borrowing, long multiplication and long division. A new method can be justified educationally only if it offers some advantage over the one it supplements or replaces, which is why comparison is a recurring theme.

Saxena conducted a comparative experimental study with 200 students, examining calculation time and error rates for addition, subtraction, multiplication and division, and reported statistically significant differences in speed and accuracy favouring the Vedic approach [13]. Its coverage of all four operations is unusual, since most studies concentrate on a single one. Dangar and Gajwani compared preservice teachers' performance on worksheets completed by conventional and Vedic techniques: 62.1% of participants using Vedic Mathematics completed problems in under five minutes and 75.8% achieved complete correctness, against 40.9% using traditional methods [1]. Khare and Gangele extended the comparison beyond elementary arithmetic by applying both approaches to analytical conics, including lines, asymptotes and conjugate hyperbolas [8]; theirs is a comparison of solution procedures applied to the same problems rather than of groups of learners.

Further studies examine Vedic teaching directly. Joshi et al. used Vedic methods to teach multiplication to fourth-grade learners and reported improved performance and faster problem solving [7]. Kumar and Joshith found that fifth-grade students taught through Vedic strategies showed significantly improved mathematical understanding compared with a conventionally taught control group [10]. Lakshmi and Stanly conducted a six-week experiment with thirty middle school students, using four sutras in 45-minute sessions three times a week; mean achievement rose from 42.5 to 68.4 (Cohen's $d = 2.67$, $p < .001$), computational accuracy from 65% to 87%, and attitude scores by 14.30 points [17]. Because that study had no comparison group, its large effect must be read with the caution that applies to every one-group design (Section 6). Table 2 summarises the principal studies.

Table 2. Summary of principal studies on Vedic Mathematics learning and performance

Study	Participants / context	Focus	Reported outcome
Saxena [13]	200 students	Four operations; calculation time and error rate	Significant differences in speed and accuracy favouring Vedic methods
Dangar & Gajwani [1]	Preservice teachers	Worksheets by conventional and Vedic methods	62.1% finished in under five minutes; 75.8% fully correct (Vedic) vs 40.9% (traditional)
Joshi et al. [7]	Grade 4 learners	Multiplication (Nikhilam, Ekadhikena Purvena)	Improved performance and speed
Kumar & Joshith [10]	Grade 5, experimental vs control	Arithmetic operations, preparatory level	Significantly improved mathematical understanding
Day-Ongao & Tan [2]	Grade 7 students	Problem solving, motivation, retention (mixed methods)	Substantial pre-test to post-test and retention gains
Lakshmi & Stanly [17]	30 middle school students, single group	Four sutras, six weeks	Achievement 42.5 to 68.4; accuracy 65% to 87%; attitude +14.30
Khare & Gangele [8]	Comparison of solution procedures	Analytical conics	Vedic sutras applied to lines, asymptotes and conjugate hyperbolas

Three observations follow. The studies converge on a favourable direction of findings. They differ widely in participants and content, so findings cannot be pooled simply. And the comparison varies: some compare methods within the same participants, some compare separate groups, and some compare only before and after an intervention.

4.2 Calculation speed and accuracy

Speed is central because many techniques are designed to simplify mental and written calculation. Saxena measured calculation time directly [13]; Dangar and Gajwani found a substantial share of participants finishing Vedic tasks within five minutes [1]; Joshi et al. [7] and Lakshmi and Stanly [17] reported faster performance in school samples. Singh and Yadav showed that Vedic sutras can give the n th term and the sum of n terms of an arithmetic progression with substantially less time in the examples examined [16], and Shembalkar et al. reviewed Vedic principles in multiplier design as a means of reducing delay in digital systems [15].

The meaning of speed deserves care. In the human studies it is the time taken by a learner to complete a set of items; in the computing studies it is the propagation delay of a circuit. The two share the logic that fewer sequential steps shorten completion time, but they should not be conflated. For learners, speed also depends on practice, familiarity and item selection; a method taught immediately before testing may show an advantage over one learned years earlier simply through recency.

Accuracy is the companion measure, since a fast method that produces errors has limited value. Saxena reported significant differences in error rates favouring the Vedic approach [13]; Dangar and Gajwani found complete correctness for 75.8% of participants using Vedic methods against 40.9% using traditional methods [1]; and Lakshmi and Stanly recorded accuracy rising from 65% to 87% [17]. The mechanisms proposed parallel the cognitive load argument: shorter procedures with fewer carried quantities offer fewer opportunities for slips, and devices such as the digit-sum check associated with the remainder sutras give a rapid test of an answer. Speed and accuracy may, however, trade off, so studies reporting both are more informative than those reporting one.

Reported differences appear to depend on at least four factors. The first is item choice: Nikhilam gives a large advantage near a base but little far from it, so a test of favourable items exaggerates the benefit while random numbers may understate it. The second is practice: a learner who has used conventional algorithms for years may initially be slower with an unfamiliar method. The third is learner characteristics, including prior attainment and confidence; the preservice teachers in [1] had considerable mathematical experience, whereas the primary pupils in [7] were still consolidating number facts. The fourth is the testing condition, including calculator use, timing and whether working is required. The finding that Vedic methods are faster or more accurate is therefore best read as conditional on particular tasks and learners.

4.3 Problem-solving skills

Day-Ongao and Tan investigated the effects of the Vedic Mathematics Technique on Grade 7 students' problem solving, motivation, post-test performance and retention. Their sequential mixed-methods explanatory study reported substantial improvement from pre-test to post-test and retention assessment, with significant differences in problem-solving performance after the intervention [2]. The qualitative strand is a strength, since it can explain how learners

experienced the technique as well as whether scores changed. Other authors link Vedic Mathematics with flexibility and mental computation [5], with critical and computational thinking and fluency while calling for more empirical research on structured learning packages [11], and with increased interest in mathematics, proposing experimental-control comparison [12].

Interpreted through Polya and Schoenfeld [25], [33], reduced calculation burden may free attention for understanding and planning, and choosing among strategies is itself a problem-solving act. On the other hand, the problems in many Vedic studies are essentially computational exercises, and improved performance on them does not necessarily indicate improvement on non-routine problems. Critical readers should ask what kind of problem solving was measured. Overall, the literature suggests a positive relationship between exposure to Vedic methods and problem-solving outcomes, though its strength may depend on learners, topic, intervention design and assessment.

4.4 Mathematical achievement

Positive achievement-related outcomes have been reported by Kumar and Joshith (fifth-grade experimental group over control) [10], Joshi et al. (fourth-grade multiplication) [7] and Lakshmi and Stanly (mean scores 42.5 to 68.4) [17]. Dangar and Gajwani add that achievement effects may include learners' experiences of the method, since they examined perceptions of practicality, clarity and attractiveness alongside performance [1], and Day-Ongao and Tan observed gains at a retention assessment as well as at the post-test [2], which matters because achievement that disappears soon after instruction has limited value.

Three cautions apply. First, if the test consists of the same kind of computational items on which the methods were practised, improvement shows acquisition of the taught procedures, a legitimate but narrower outcome than general achievement. Second, effect sizes are conventionally read against Cohen's benchmarks of 0.2 (small), 0.5 (medium) and 0.8 (large) [44]; the very large effect in a short single-group study [17] more likely reflects the combined influence of teaching, practice, test familiarity and novelty than the sutras alone. Third, content and grade level differ, since multiplication in Grade 4 [7] and arithmetic operations at the preparatory level [10] address different developmental stages. Taken as a whole, the research supports the proposition that Vedic Mathematics can be taught successfully and that learners perform well on the tasks involved. It does not yet establish superiority over well-designed conventional approaches in producing deep and transferable achievement, as the more cautious authors acknowledge [11], [14].

4.5 Affective outcomes: attitude, motivation, anxiety and engagement

Day-Ongao and Tan examined motivation toward mathematics as a principal outcome [2]; Lakshmi and Stanly reported an average gain of 14.30 points in attitude scores [17]; Dangar and Gajwani gathered perceptions of practicality, clarity and attractiveness [1]; and Resic and Lemo discussed the potential to increase interest in mathematics [12]. These outcomes matter in light of research on mathematics anxiety, which Ashcraft describes as tension, apprehension or fear that interferes with performance and reduces working-memory capacity during calculation [23], and which Hembree's meta-analysis linked to lower achievement while showing that treatments can improve performance [24]. If Vedic techniques make calculation seem shorter and more manageable, they might reduce the sense of threat for anxious learners. No reviewed study measured anxiety with a validated scale, so this remains a hypothesis consistent with, but not confirmed by, the attitude findings.

Boaler argues that learners who see mathematics as flexible and creative, with numbers handled in different ways, develop more productive attitudes than those who see it as rules to be reproduced [45]; the emphasis on alternative methods in Vedic Mathematics [5] resembles that view. The novelty of an unfamiliar method may, however, produce short-term enthusiasm that fades, an effect rarely controlled, and long-term follow-up of affective outcomes is lacking. Teacher attitudes are also likely to determine adoption: preservice teachers who find the methods clear and practical are more likely to use them [1], yet few studies follow trainees into practice.

5. Applications of Vedic Mathematics

5.1 Arithmetic

Arithmetic is where Vedic Mathematics has been most directly applied. Khatri describes uses in addition, subtraction, multiplication, division, squaring, cubing, roots, fractions, powers and divisibility, arguing that the techniques have an organised algebraic basis [9]. Multiplication is the most prominent target because the long-multiplication algorithm involves many partial products and carries and because the Vedic repertoire offers alternatives chosen by the numbers involved. A learner using Nikhilam works with small deficiencies instead of large digits, whereas Urdhva-Tiryagbhyam is a general method for any pair of numbers [7]. Research on Dutch mental strategies has shown that

strategy families, such as splitting by place value versus working with whole numbers, have distinct strengths and error patterns [35]; Vedic alternatives can be seen as an additional strategy family.

For addition, subtraction and division, comparative evidence is scarcer. Saxena's four-operation comparison is a rare exception [13], and the advantages over conventional algorithms are more modest and less often tested. Singh and Yadav extend the discussion to sequences and series [16], but their evidence is demonstrative and includes no learner data. The better-evidenced applications therefore concentrate on whole-number multiplication, while fractions, decimals, percentages and roots, which Khatri lists [9], have little experimental coverage.

5.2 Algebra, geometry and computing

Devi explains applications in algebra and the possibility of simplifying problem solving [3]; Shekhar's review extends scope to geometry and calculus [14]; and Khare and Gangele apply sutras such as Paravartya, Urdhva-Tiryagbhyam, Adyam-Adyena and Lopana-Sthapana to conics [8]. Algebraic applications are theoretically interesting because they expose structure beneath the arithmetic devices: Urdhva-Tiryagbhyam for two-digit numbers is in effect the multiplication of two linear polynomials, so a learner who sees this may come to regard arithmetic and algebra as continuous.

Beyond school mathematics, Vidhya et al. discuss Nikhilam and Ekadhikena Purvena in engineering contexts including signal processing, control systems, encryption and optimisation [6]. The best-known computing work follows Thapliyal and Srinivas, who proposed multiplier architectures in which Urdhva-Tiryagbhyam generates partial products in parallel, aiming to reduce delay relative to shift-and-add designs [21]; Shembalkar et al. review such designs [15]. Because circuits operate on binary numbers, the sutra is adapted rather than applied literally, and the claims concern hardware performance, not classroom learning. This evidence shows the transferability of an idea about organising partial products, not the pedagogical effectiveness of Vedic Mathematics. Table 3 summarises the areas of application and the nature of the evidence.

Table 3. Areas of application, sources and nature of evidence

Area of application	Sources	Nature of evidence
Whole-number arithmetic	[7], [9], [10], [13]	Experimental, comparative and descriptive
Arithmetic progression	[16]	Demonstrative worked examples
Algebra	[3], [9], [14]	Expository and review
Analytical geometry	[8]	Comparison of solution procedures
Engineering applications	[6]	Conceptual discussion and case examples
Digital multiplier design	[15], [21]	Review and hardware design studies
Educational theory	[11]	Conceptual analysis

5.3 Teacher education

Dangar and Gajwani treated Vedic techniques as content that future teachers must themselves learn before they can teach it [1]. The point is important because a teacher who knows only the steps will present a rule, whereas one who understands the underlying identity can show why it works, connect it to algebra and help learners decide when it is suitable. The proficiency literature supports the view that teachers' conceptual understanding is a precondition for developing the same in learners [29]. Studies of learner outcomes and of teacher preparation are therefore complementary, and the benefits reported for learners can be expected to depend partly on the preparation examined in the latter.

6. Methodological Patterns and Critical Appraisal

A review must evaluate as well as report. The empirical literature includes quasi-experimental comparisons with a control group [10], [13]; within-participant comparisons of two methods [1]; mixed-methods designs [2]; single-group pretest–posttest designs [17]; and analytical or demonstrative comparisons without learner data [8], [16]. A single-group design cannot separate the effect of the intervention from maturation, repeated testing or the effects of extra instruction and attention, and its large effects should not be compared directly with those from controlled studies. Controlled designs are stronger but face threats of their own, notably pre-existing differences when intact classes rather than randomly assigned students form the groups.

Sample sizes range from a few dozen learners to about two hundred [13], [17], and many interventions last only a few weeks, so findings reflect short-term learning. Participants include primary pupils, middle school students and preservice teachers [1], [2], [7], [10], [17], and an effect at one level may not appear at another. Outcomes include

completion time, error rate, percentage of fully correct worksheets, test scores, attitude scales and perceptions; many are researcher-made and evidence of reliability and validity is not always reported. Measures of speed and accuracy on the taught procedures are closely aligned with the intervention, which raises the chance of detecting an effect but limits claims about transfer.

Finally, sources range from established journals to conference papers, review articles and contributions in less selective venues, and most reported studies find favourable results, which may reflect publication bias in a field that attracts advocates. The literature should therefore be treated as promising but provisional, the stance taken by authors who call for more systematic testing and better integration with contemporary curricula [11], [14].

7. Policy and Curricular Context

The research has taken place against curricular reform in India. The National Curriculum Framework 2005 emphasised reducing rote learning, connecting knowledge to life outside school and developing mathematical thinking rather than skill in procedures alone [42]. The National Education Policy 2020 calls for greater emphasis on conceptual understanding, mathematical thinking and the integration of Indian knowledge traditions [43]. Some institutions have taken these documents as encouragement to include Vedic Mathematics in school and college programmes, and several universities and state authorities have introduced skill or elective courses.

This makes empirical evaluation more urgent. The emphasis on conceptual understanding can support Vedic Mathematics when it is taught with reasons and as alternative strategies [5], [9], but it can equally caution against a version learned as shortcuts without understanding, which is Skemp's instrumental understanding [26]. Evidence is needed to show which version yields the desired outcomes. Reported gains typically involve a teacher or researcher who has prepared the techniques, provided worked examples and allowed time for practice [7], [17]; whether similar results hold in ordinary classrooms with larger classes and untrained teachers has seldom been tested. Introducing alternative methods also carries an opportunity cost in a full curriculum, and a balanced evaluation should weigh reported benefits against such constraints.

8. Synthesis and Research Gap

8.1 Synthesis

The literature falls into four strands. The descriptive and conceptual strand [4], [5], [9], [11], [12], [14] establishes what Vedic Mathematics is and why it might support learning; its hypotheses about cognitive load, flexibility and understanding are only partially tested. The comparative and experimental strand [1], [2], [7], [10], [13], [17] provides evidence on speed, accuracy, problem solving and achievement; its findings are consistently favourable but drawn from different grade levels, topics and designs, with the strongest designs using control groups [10], [13] and the largest effect arising from a single-group design [17]. The application strand [3], [6], [8], [15], [16] shows that the sutras can be used in algebra, analytical geometry, sequences and digital design, mostly through demonstration. The critical and historical strand [19], [20], [22] shows that claims of Vedic origin are disputed but that educational value can be judged independently.

Five points of agreement emerge. Vedic Mathematics is a coherent set of alternative strategies with algebraic justification; its techniques frequently reduce the number of steps; learners taught them usually perform well on tasks involving them; attitudes toward mathematics tend to be positive; and the strength of the evidence is limited by small samples, short interventions and heterogeneity of design.

8.2 Research gap

Several gaps remain. First, many studies focus on specific operations or topics, such as multiplication, arithmetic operations, arithmetic progression or analytical conics, rather than a broad and systematically defined set of problems [7], [8], [10], [16]. Second, participant groups differ, including school students and preservice teachers, which hinders comparison across educational levels [1], [2], [10]. Third, conceptual reviews call for more systematic empirical testing and better curricular integration [11], [14], Pimpalkar specifically noting the lack of research on structured Vedic learning packages [11], while proposed engineering applications rest on examples and case studies needing validation [6], [15]. Fourth, methodological quality is uneven: some of the most striking effects come from designs without control groups [17], many interventions are short, and few studies report instrument reliability or the amount of practice given to each compared method. Fifth, mathematics anxiety, long-term retention and transfer to non-routine problems have been little studied, although theory suggests they are central to the claim that alternative strategies improve learning [23], [34].

Finally, relatively few studies simultaneously examine speed, accuracy, problem-solving performance and mathematical achievement using a clearly controlled comparison between Vedic and conventional methods. A focused study using clearly defined tasks and measurable performance indicators could clarify not only whether differences occur but which aspects of mathematical performance are most closely associated with Vedic techniques.

9. Conclusion

This review has traced Vedic Mathematics from its origin and organisation, through the contested debate about the provenance of its sutras, to the theoretical perspectives that explain why alternative strategies might influence learning. The empirical literature associates the approach with faster and more accurate calculation, improved problem solving, higher achievement on taught tasks and more favourable attitudes, and shows applications in arithmetic, algebra, analytical geometry, sequences and digital multiplier design. At the same time, the evidence is diverse and uneven, with small samples, short interventions, varied designs and limited attention to anxiety, retention and transfer.

Vedic Mathematics is therefore best regarded as a promising but provisional set of alternative calculation strategies whose educational value does not hinge on the dispute over its antiquity. Whether it improves learning beyond well-designed conventional instruction depends on how it is taught, what is measured, and for whom. Future research should use controlled designs with equated instruction, validated instruments, long-term follow-up and tasks extending beyond whole-number multiplication, and should examine speed, accuracy, problem solving and achievement together.

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