



Specialized Montessori Materials and Numerical Sequencing Skills in a Private Pre-Primary School in Pwani Region, Tanzania

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Abstract: Early numeracy is foundational for mathematics, yet settings struggle to translate abstract number concepts into experiences. This study explored how Montessori pedagogy supports early numeracy in Pwani Region, Tanzania. The article addresses the objective of examining how specialized Montessori materials support numerical sequencing skills. A qualitative interpretivist approach and single-site case-study design were adopted. Eight participants-six pre-primary teachers and two administrative leaders-were selected through purposive and total-population sampling. Semi-structured interviews, classroom observations, and document analysis generated evidence. After university and administrative clearance, the researcher observed four morning work cycles, documented teacher-child interactions, reviewed lesson plans and learner records, and conducted interviews lasting 30–45 minutes. Transcripts, field notes, and documents were coded thematically, compared constantly, and synthesized narratively. Credibility and content validity were strengthened through triangulation, supervisor review, member checking, thick description, piloted observation routines, an audit trail, and documented coding; dependability and confirmability replaced statistical reliability. Ethical protections included informed consent, voluntary participation, withdrawal rights, pseudonyms, confidentiality, parental notification, secure records, and non-intrusive observation. Findings showed that Number Rods physicalized ordered magnitude; Sandpaper Numerals developed tactile symbol memory; Spindle Boxes concretized zero and enabled self-correction; and material mastery transferred to Tanzania Institute of Education sequencing, matching, and number-writing tasks. The study concludes that specialized materials operate as sensory and semiotic bridges from quantity to symbol while shifting error detection toward the learner. It recommends protecting uninterrupted work cycles, maintaining complete material sets, training teachers in precise presentations, incorporating affordable local manipulatives into national guidance, and evaluating transfer to mathematics outcomes

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INTRODUCTION

Early numeracy comprises more than reciting number names: children must coordinate quantity, order, symbols, one-to-one correspondence, magnitude, and the meaning of zero. Learning trajectories research shows that young children build mathematical understanding through sequenced experiences that connect actions, representations, and increasingly abstract ideas (Piaget, 1954; Baroody, Lai, & Mix, 2006; Clements & Sarama, 2014; Clements & Sarama, 2014). Montessori education addresses this developmental problem through a prepared environment containing ordered, hands-on materials that isolate particular mathematical relationships. Number Rods embody continuous magnitude, Sandpaper Numerals connect tactile movement with written symbols, and Spindle Boxes coordinate counting, cardinality, sequence, and zero.

International research provides qualified support for Montessori education. A longitudinal lottery-based study found stronger growth in academic achievement and several developmental outcomes among children attending high-fidelity Montessori preschools, while identifying spatially organized mathematics materials as a plausible contributor (Lillard et al., 2017; Lillard et al., 2017). A wider review concludes that fidelity, teacher preparation, uninterrupted work periods, and the availability of Montessori materials influence outcomes, and it cautions against attributing all observed differences to materials alone (Marshall, 2017; Marshall, 2017). The relevant question for practice is therefore how children and teachers actually use specialized materials to construct numerical understanding within a particular classroom.

Tanzania's pre-primary curriculum expects learners to count, order, match quantities and symbols, complete simple sequences, and represent numbers graphically (Tanzania Institute of Education [TIE], 2016; Tanzania Institute of Education [TIE], 2016). However, localized qualitative evidence on the concrete-to-symbolic transition is limited, especially in peri-urban private schools. This article draws on a case study at Martha of Bethany Montessori Pre and Primary School in Kibaha District. Its main objective is to explore how specialized Montessori learning materials support numerical sequencing skills. The analysis integrates teacher accounts, observed child-material interactions, and documentary evidence, then interprets those findings through Montessori's developmental concepts, Vygotsky's Socio-Cultural Theory, and Bronfenbrenner's Ecological Systems Theory.

Literature Review

1. Theoretical Review

Montessori's Theory of Natural Development provides the first analytical lens. The absorbent mind and sensitive periods describe young children as especially receptive to order, movement, language, and sensory refinement (Montessori, 1967; Montessori, 1967). The "mathematical mind" develops through purposeful activity in an ordered environment, not through verbal explanation alone. Specialized mathematics materials isolate difficulty, embody a progression from concrete quantity to abstract symbol, and contain a control of error that allows children to recognize discrepancies. From this perspective, numerical sequencing emerges when the child repeatedly coordinates sight, touch, movement, language, and spatial order.

Vygotsky's (1978) Socio-Cultural Theory explains how materials and guided interaction mediate this development (Feuerstein, Rand, Hoffman, & Miller, 1980). Number Rods, Sandpaper Numerals, and Spindle Boxes function as cultural and semiotic tools that externalize magnitude, sequence, and symbol-quantity relations. The teacher operates as a more knowledgeable other within the child's Zone of Proximal Development by presenting precise actions and language, then withdrawing assistance as the child gains control. The material's built-in feedback extends this scaffold: it makes an error perceptible without immediate adult judgment and supports the movement from socially guided performance toward independent self-regulation.

Bronfenbrenner's (1979) Ecological Systems Theory situates child-material activity within nested conditions. The prepared classroom is the microsystem; home-school expectations form a mesosystem; school purchasing, maintenance, scheduling, and staff development operate through the exosystem; and national curriculum standards form part of the macrosystem. This lens prevents an overly individual explanation of learning. A well-designed material supports sequencing only when it is complete, accessible, accurately presented, and afforded sufficient uninterrupted time. The combined framework therefore links individual sensory construction, social mediation, and institutional conditions.

2. Empirical Review

Evidence on Montessori outcomes is generally positive but heterogeneous. Lillard et al. (2017) followed 141 children admitted or not admitted to high-fidelity public Montessori preschools through a lottery and found stronger academic growth over time among Montessori pupils. Their analysis proposed embodied and spatial mathematics work as one possible mechanism: Number Rods transform systematically varying lengths into named numerical units. Marshall's (2017) review similarly found that program fidelity and engagement with authentic Montessori materials matter, while noting that causal evidence for individual materials remains limited.

Broader early mathematics research supports the concrete-to-abstract logic without implying that manipulatives work automatically (Klibanoff et al., 2006). Clements and Sarama (2014) describe learning trajectories in which children progress through increasingly sophisticated levels of thinking when tasks, representations, and teacher support are deliberately sequenced. Physical objects can make relations visible, but children must connect the objects to mathematical meaning. Montessori materials address this requirement through stable visual, tactile, and spatial correspondences—for example, incremental rod length for magnitude and empty space in the zero compartment for the absence of quantity.

The Tanzanian policy context makes transfer especially important. The national pre-primary curriculum expects practical activity to lead toward recognized competencies in counting, sequencing, matching, and written number representation (TIE, 2016; TIE, 2016). The dissertation's review identifies a gap in thick, classroom-level evidence from peri-urban Pwani: existing studies rarely document the moment a child detects a sequencing discrepancy, reorganizes materials, or transfers mastery to workbook tasks. The present article addresses that gap through triangulated observation, participant testimony, and school records rather than standardized achievement comparisons.

METHODOLOGY

The study adopted a qualitative interpretivist approach and a single-site case-study design to examine specialized Montessori materials in the natural setting of Martha of Bethany Montessori Pre and Primary School, Kibaha District, Pwani Region. The reported sample comprised eight participants: six pre-primary teachers and two key administrative informants, namely the academic teacher and head of school. The school was purposively selected as an active Montessori case, and total-population sampling included the personnel responsible for early numeracy instruction and supervision. Semi-structured interview guides, a qualitative observation schedule, and a document-analysis protocol were used, with the researcher serving as the primary interpretive instrument. Following academic clearance from St. Augustine University of Tanzania and administrative permission, non-participant observations were conducted during four morning work cycles from July 20 to July 23, 2026, for two hours daily. The researcher documented material selection, presentations, teacher-child interaction, the prepared environment, and control-of-error episodes. Lesson plans, schemes of work, learner progress records, exercise books, and material inventories were reviewed for corroboration. Interviews lasting 30–45 minutes were conducted after school in a private location, audio-recorded with consent, and transcribed verbatim. The detailed methodology reports eight participants but later refers once to seven interviewees and elsewhere to eight transcripts; this inconsistency is acknowledged and the stated sample of eight is retained. Analysis involved familiarization, descriptive coding, theme development aligned with the objectives, narrative synthesis, and constant comparison across interviews, observations, and documents. In qualitative terms, validity and reliability were addressed as trustworthiness. Credibility and content validity were supported through methodological triangulation, supervisor review of draft instruments, member checking, and prolonged contextual engagement. Thick description supported transferability; piloted observation routines and documented procedures supported dependability; and raw field notes, transcripts, coding frameworks, and an audit trail supported confirmability. Ethical safeguards included university and school authorization, adult written consent, voluntary participation and withdrawal, pseudonyms, confidentiality, parental or guardian notification for observed children, non-intrusive classroom presence, and password-protected data storage.

FINDINGS AND DISCUSSION

The selected objective examined how specialized Montessori materials supported numerical sequencing and foundational counting. Four interrelated themes were evident across interviews, observations, and documents: physicalization of magnitude through Number Rods; tactile symbol formation through Sandpaper Numerals; independent error detection and the concept of zero through Spindle Boxes; and transfer from concrete mastery to TIE-aligned written competencies. The analysis below gives priority to participants' own explanations and to detailed episodes from the July 2026 work-cycle observations. Quotations are identified by participant pseudonym, while observational and documentary evidence is used to corroborate or qualify each account.

Table 1
Triangulated Functions of Specialized Montessori Numeracy Materials

Material	Sequencing mechanism	Corroborating evidence
Number Rods	Incremental length and alternating units physicalize ordered magnitude from 1 to 10.	Child independently corrected an irregular 9–7 step and completed the staircase.
Sandpaper Numerals	Tactile tracing links directional movement, visual form, and numerical symbol.	Teacher testimony and transition from tracing to chalk/pencil formation.
Spindle Boxes	Exact distribution links symbols 0–9 to cardinal quantities and makes zero an empty set.	Child detected three extra spindles, restarted, and completed all 45 accurately.
Numbers and Counters	Pairs ordered symbols with discrete quantities and exposes odd/even spatial patterns.	Teacher accounts and TIE-aligned matching and sequence records.

Source: Field interviews, classroom observations, and documentary evidence (2026).

Number Rods Made Ordered Magnitude Visible and Tangible

The Number Rods transformed sequence into a graduated physical relationship. Teacher B explained: “The Number Rods show children that 10 is not just a digit; it is physically ten times longer than 1. When a child holds the rod for 1 in one hand and the rod for 10 in the other, they feel the weight difference” (Teacher B, interview, 2026). The same participant added that the alternating red and blue sections allow children to “physically construct the staircase of quantities from shortest to longest” instead of memorizing “1, 2, 3” as a nursery rhyme. This account indicates that sequence was learned as an ordered relation among magnitudes, not merely as a recited string of number names.

The Day 4 observation on July 23 supplied behavioral evidence for Teacher B's interpretation. A child independently carried all ten rods from the low shelf to a floor mat, aligned their left edges, and constructed the staircase. After placing rod 7 directly beneath rod 9, she paused because the unusually wide step disrupted the visual pattern. Without teacher correction, she removed rod 7, located rod 8, inserted it between rods 9 and 7, and continued until rod 1 completed the sequence. The episode showed simultaneous use of ordinal reasoning, visual discrimination, length comparison, motor coordination, and the material's built-in control of error.

The classroom arrangement reinforced this learning mechanism. Field notes recorded ten rods ranging from 10 centimetres to one metre, each divided into alternating 10-centimetre color units and displayed on accessible shelving. The constancy of the unit and the systematic change in total length made 'one more' visible across successive quantities. The observation therefore corroborated the interview evidence: children could inspect an error through spatial disharmony and repair the ordered relation through action.

This finding supports Montessori's concept of the mathematical mind and sensitive period for order: the prepared material externalizes a regular sequence that the child can reconstruct through purposeful movement (Montessori, 1967; Montessori, 1967). Vygotsky's (1978) theory adds that the rod system is a semiotic tool mediating the transition from physical

magnitude to internal numerical order. The finding is consistent with Lillard et al. (2017), who identify spatially organized Number Rod work as a plausible mechanism for Montessori mathematics learning, and with Clements and Sarama's (2014) principle that children progress when representations embody increasingly explicit mathematical relations.

The result also qualifies claims that concrete materials are beneficial simply because they are attractive or hands-on (Boaler, 2015). What mattered was the mathematical structure embedded in the apparatus: equal color units, graduated length, a fixed order, and a visible consequence when a rod was misplaced. This interpretation agrees with Marshall's (2017) review, which emphasizes program fidelity and purposeful material use, and with Clements and Sarama's (2014) warning that manipulatives support learning only when children connect physical features to the intended mathematical relation.

Sandpaper Numerals Connected Tactile Memory to Symbol Formation

Sandpaper Numerals supported the symbolic side of sequencing by coupling each visual digit with a repeatable motor pathway. Teacher C stated: "Before a child picks up a pencil to write a number in an exercise book, their fingers must know the shape of that number. The sandpaper gives sensory feedback. If the child's finger strays off the sand onto the smooth wood, they feel it immediately" (Teacher C, interview, 2026). The participant further explained that "by the time they pick up chalk or a pencil, their hand remembers the movement naturally." The quotation identifies touch as feedback, but also as rehearsal for directionality and symbol formation.

Classroom evidence showed that tactile work was not an isolated end point. The dissertation's photographic and field documentation recorded a child tracing a Sandpaper Numeral and subsequently writing the corresponding digit on a handheld chalkboard. Learner exercise books later contained written numerals and number words. This sequence of artifacts—from rough-surface tracing, to chalk movement, to workbook production—corroborated Teacher C's claim that repeated movement supported graphic recall. It also showed that the teacher did not abandon formal symbol work; instead, the sensory material prepared the child to perform it with less dependence on verbal correction.

The material itself contributed a limited control of error. A finger leaving the rough numeral and touching the smooth board produced an immediate change in sensation, allowing the learner to notice deviation during the movement. Yet the evidence also indicated that accurate initial presentation remained important: the tracing pathway and starting point had to be demonstrated before the child could reproduce them independently. Material feedback and teacher mediation were therefore complementary rather than competing influences.

The result reflects Montessori's sensitive periods for movement, sensory refinement, order, and language (Montessori, 1967; Montessori, 1967). It also demonstrates Vygotskian internalization: a culturally designed physical trace first guides action externally, then becomes a remembered symbolic movement (Vygotsky, 1978; Vygotsky, 1978). Lillard et al. (2017) similarly argue that Montessori presentations capitalize on embodied cognition, although Marshall (2017) cautions that materials cannot be separated completely from teacher interaction and fidelity. The present evidence supports that caution because accurate directional presentation preceded independent writing.

In relation to earlier research, the observed transition from tracing to writing is compatible with Lillard et al.'s (2017) account of embodied and sequential Montessori learning. However, the present study adds process-level evidence from a Tanzanian classroom: it identifies the sensory contrast that signaled an error and documents the intermediate chalkboard stage before workbook writing. Because no handwriting scale or comparison group was used, the finding is best understood as a credible pathway reported by participants and corroborated in artifacts, not as proof that Sandpaper Numerals caused superior handwriting.

Spindle Boxes Enabled Self-Correction and Concretized Zero

Participants consistently described Spindle Boxes as a bridge among symbol recognition, exact quantity, numerical order, and zero. Teacher C explained: “In traditional teaching, zero is very abstract and hard to explain to a four-year-old. But with the Spindle Box, compartment 0 receives nothing.” The teacher continued, “The child looks at all the other compartments filled with wooden spindles and sees that 0 is empty. The physical absence of spindles makes 'zero' tangible” (Teacher C, interview, 2026). This qualitative evidence shows how an empty compartment represented zero positively as an intentionally empty set, rather than as a missing response.

Teacher A located the same material within a broader progression: “When children work with the Spindle Boxes and Numbers and Counters, they are not just playing with wood; they are building the mental map for numerical sequencing.” According to the teacher, once children's hands understood quantity and order, they could count objects and write number sequences “without skipping” (Teacher A, interview, 2026). Leader G emphasized learner agency, stating that “the teacher does not need to mark the child's work with a red pen”; instead, the material tells the child, “Something is wrong here,” and self-correction builds confidence and problem-solving (Leader G, interview, 2026).

The Day 3 observation on July 22 directly illustrated these accounts. After distributing spindles across compartments 0–9, a boy found three spindles remaining in his hand. He inspected the empty zero compartment and the filled compartments 1–9, paused, and then emptied the entire box without seeking assistance. On his second attempt he whispered the number sequence while recounting. His final spindle completed compartment 9, leaving his hand empty and all 45 spindles correctly distributed. He smiled, tied the grouped quantities, and returned the material to the shelf. The episode contained not only a correct final answer, but also error detection, strategy revision, sustained attention, and independent verification.

Triangulation strengthened this theme. The material inventory confirmed that the two boxes were labeled 0–4 and 5–9 and accompanied by exactly 45 loose spindles; consequently, an incorrect distribution necessarily produced a surplus or shortage. The physical remainder functioned as feedback that did not require an adult to disclose the error. This design linked ordinal position, cardinal quantity, one-to-one correspondence, and the empty set in a single exercise.

Montessori theory interprets control of error as a means of transferring evaluation from adult authority to the child's purposeful activity. Vygotsky's (1978) framework explains the same event as scaffolded self-regulation: the artifact carries culturally organized feedback that the learner gradually internalizes. The independent restart also aligns with mastery-oriented behavior reported in high-fidelity Montessori settings (Lillard et al., 2017; Lillard et al., 2017).

Nevertheless, the case evidence shows a mechanism rather than a measured causal effect; future studies should test whether repeated control-of-error work predicts durable sequencing performance.

The findings extend the discussion beyond correctness. The boy's decision to restart demonstrated persistence and metacognitive monitoring, while Leader G's account suggested a less punitive error culture than conventional red-pen correction (Murayama, Pékary, & Suzuki, 2016). This interpretation is consistent with Lillard and Heise's (2016) evidence that fidelity to core Montessori materials can influence child outcomes and with Marshall's (2017) conclusion that Montessori's interdependent design features should be examined as a system. At the same time, the single observed episode cannot establish how frequently all learners self-correct; it provides a detailed example of the process the participants described.

Concrete Mastery Transferred to National Curriculum Tasks

Participants explicitly rejected the assumption that time spent with concrete materials delayed academic work. Teacher A stated that after quantity and order were established physically, “moving to pencil-and-paper work becomes natural,” and children could “write numbers in sequence without skipping” and spell number words because “the concept is already fixed in their minds” (Teacher A, interview, 2026). This account framed written work as the later representation of an understood relation, rather than the first means of teaching it (Skemp, 1989).

Leader F offered school-level corroboration: “Parents sometimes worry that working with wooden materials delays standard pen-and-paper writing. However, our internal assessment records show the exact opposite.” The academic leader reported that children given adequate time with Sandpaper Numerals and Spindle Boxes “transition seamlessly to the Tanzania Institute of Education pre-primary syllabus workbooks,” with “cleaner” symbol formation and a “far more stable” number sequence than among children pushed into rote writing too early (Leader F, interview, 2026). This quotation is important because it links material use to the institutional demand for visible written performance, while also revealing parental pressure that may encourage premature workbook instruction.

Document analysis provided a third evidence stream. Lesson plans and learner work displayed TIE-aligned tasks involving matching printed items to numbers, filling missing numbers in sequences from 1 to 10, grouping and counting objects, writing digits, and writing number words such as 'one', 'two', and 'three'. The documents showed correspondence between the concepts embodied in the materials and the competencies demanded in classroom records. They did not, however, provide a controlled comparison with non-Montessori pupils; the evidence demonstrates curricular alignment and observed transfer within the case school.

This finding demonstrates alignment rather than competition between Montessori practice and national expectations. In Bronfenbrenner's (1979) terms, the material-based classroom microsystem connected productively with the curriculum macrosystem. It also fits learning-trajectories theory: concrete activity is educationally valuable when it advances toward explicit representational goals (Duckworth, 2016 ; Clements & Sarama, 2014; Clements & Sarama, 2014). The result supports TIE's (2016) activity-oriented curriculum and echoes Lillard et al. (2017), whose longitudinal study found stronger academic growth in high-fidelity Montessori settings. Because the present case did not administer standardized tests, the

evidence should be interpreted as observed and documented transfer, not comparative effectiveness.

The convergence of teacher testimony, leadership records, classroom observation, and learner work increases the credibility of the transfer claim. The interpretation also responds to Marshall's (2017) concern about treating Montessori materials as isolated objects: the effect described by participants depended on a sequence of accurate presentation, repeated independent manipulation, self-correction, and later symbolic application. Thus, the practice was not a choice between play and curriculum; it was a structured route from concrete quantity to national curriculum representation.

Integrated Interpretation of The Findings

Across the four themes, specialized materials functioned as a connected representational system. Number Rods embodied continuous magnitude and order; Sandpaper Numerals embodied the movement required to form symbols; Spindle Boxes joined ordered symbols to exact cardinal quantities and an empty set; and Numbers and Counters paired discrete quantities with ordered numerals. Teacher A summarized this cumulative logic by describing a “mental map for numerical sequencing” built through the hands. Observations supported that interpretation because children did not merely handle objects: they compared, ordered, counted, noticed discrepancies, revised strategies, and moved from material action to written representation.

The combined theoretical framework explains different dimensions of this system. Montessori's theory accounts for the developmental fit of order, movement, sensory discrimination, independence, and control of error within a prepared environment (Montessori, 1967; Montessori, 1967). Vygotsky's (1978) Socio-Cultural Theory explains the materials as culturally designed semiotic tools: teacher demonstrations initially mediate action within the Zone of Proximal Development, after which the child internalizes the sequence and assumes greater control. Bronfenbrenner's (1979) theory explains why this child-material interaction depends on wider systems, including teacher preparation, school timetables, procurement, parental expectations, and national curriculum standards.

The results are broadly consistent with Lillard et al. (2017), who reported stronger academic growth in high-fidelity Montessori preschool and identified embodied, spatially organized mathematics as a plausible mechanism. They also agree with Lillard and Heise (2016), whose classroom study suggests that fidelity to core Montessori materials matters, and with Clements and Sarama (2014), who argue that effective early mathematics instruction connects actions and representations through deliberate trajectories. The present study contributes contextual detail by showing precisely how a sequencing discrepancy became visible, how a learner independently repaired it, and how schools linked this material mastery to Tanzanian workbook tasks. Consistent with Marshall (2017), the findings should not be generalized as proof that a single apparatus independently causes achievement; they show a credible mechanism operating within a particular prepared environment.

Implications for Policy and Practice In Tanzania

At policy level, the findings imply that the Tanzania Institute of Education and the ministry responsible for education should make the concrete-to-symbol progression more

explicit in pre-primary curriculum guidance. National materials should illustrate how quantity, sequence, zero, and written symbols can be developed through graduated manipulatives before repetitive copying. Resource guides should specify the mathematical properties that must be preserved—equal units, ordered progression, exact quantities, an intentional empty set, and a built-in means of checking—so that Montessori-informed resources are understood as structured learning tools rather than classroom toys.

A second policy implication concerns access and procurement. Reliance on imported wooden apparatus could widen differences between well-resourced private schools and public or community pre-primary classes. TIE and education authorities should therefore develop standards for affordable, safe, dimensionally accurate materials that can be fabricated locally from wood, card, cloth, bottle tops, or other durable resources. Approval should depend on preservation of the concept and control of error, not on imitation of an expensive commercial appearance. Public procurement frameworks could bundle basic numeracy manipulatives with pre-primary learning packages and include budgets for replacement of missing pieces, because incomplete sets weaken the feedback mechanism demonstrated in this study.

Teacher policy should move beyond general encouragement to use teaching aids. Pre-service and in-service programmes should require practical competence in presenting Number Rods, Sandpaper Numerals, Spindle Boxes, and locally adapted equivalents; observing without premature correction; identifying when control of error is functioning; and linking material mastery to TIE competencies. Assessment of trainees should include live demonstration and interpretation of child activity, not written definitions alone. Cluster-based mentoring and lesson-study sessions could allow experienced teachers to model economical language, movement, material sequencing, and documentation for teachers who lack specialized Montessori preparation.

Quality assurance also needs a broader evidence base. School inspection and internal supervision should not judge pre-primary learning primarily by the volume of completed exercise-book pages. Indicators should include the accessibility and completeness of manipulatives, opportunities for uninterrupted child work, accuracy of teacher presentations, evidence of independent self-correction, and documented progression from concrete quantity to symbols and written tasks. This would align supervision with the TIE (2016) activity-oriented curriculum while reducing pressure to introduce rote copying before children understand number relations.

For classroom practice, schools should protect sufficiently long work periods so children can select, complete, check, repeat, and return materials without artificial interruption. The Day 3 and Day 4 observations show why time matters: self-correction required the learner to pause, inspect the discrepancy, dismantle part or all of the work, and reconstruct the sequence. Teachers should resist correcting immediately when the material can disclose the error, but should intervene with a brief re-presentation when the child cannot interpret the feedback. Individual observation records can document whether a learner orders magnitudes, associates symbols with quantities, treats zero as an empty set, counts with one-to-one correspondence, and transfers learning to TIE tasks.

School leaders should maintain complete inventories, schedule regular presentation rehearsals, and connect material observations to weekly planning and learner progress records. Parent engagement is equally important. Demonstration sessions can show families

how tracing, carrying rods, counting spindles, and rebuilding a sequence prepare children for legible numerals, missing-number tasks, and number words. Making this pathway visible may reduce parental demand for premature workbook completion. In combination, these measures would support pedagogical fidelity, equitable access to concrete numeracy experiences, and accountable progression toward national learning expectations.

CONCLUSION AND RECOMMENDATIONS

The study concludes that specialized Montessori materials supported numerical sequencing by making mathematical relations perceptible, actionable, and self-correcting. Number Rods embodied ordered magnitude; Sandpaper Numerals connected tactile movement to symbol formation; Spindle Boxes linked symbols to exact quantities, represented zero as an empty set, and enabled independent correction; and Numbers and Counters reinforced ordered discrete quantity. Interviews, observed work cycles, and learner records converged in showing movement from sensory manipulation to TIE-aligned sequencing and writing tasks. The findings therefore substantiate the combined theoretical framework: Montessori explains the developmental fit of ordered sensory materials, Vygotsky explains mediation and internalization, and Bronfenbrenner explains why classroom outcomes depend on institutional and curriculum alignment.

School leaders should protect uninterrupted work cycles, maintain complete material inventories, and provide regular presentation rehearsals so that every teacher uses the apparatus accurately. Teachers should document each learner's progression from material manipulation to symbols and written tasks, while preserving opportunities for independent error detection. TIE and teacher-education providers should include low-cost, dimensionally accurate local manipulatives and control-of-error principles in pre-primary guidance rather than treating imported equipment as the only route to Montessori-informed practice. Parents should be shown how concrete work prepares children for written curriculum expectations. Future multi-site and longitudinal research should reconcile participant reporting, combine qualitative process evidence with standardized numeracy measures, and examine whether observed gains in sequencing, zero understanding, and self-correction persist into primary mathematics.

REFERENCES

- Baroody, A. J., Lai, M.-L., & Mix, K. S. (2006). The development of young children's number and operation sense and its implications for early childhood education. In B. Spodek & O. N. Saracho (Eds.), *Handbook of research on the education of young children* (2nd ed., pp. 187–221). Lawrence Erlbaum Associates.
- Boaler, J. (2015). *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. Jossey-Bass.
- Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Harvard University Press.
- Clements, D. H., & Sarama, J. (2014). *Learning and teaching early math: The learning trajectories approach* (2nd ed.). Routledge. <https://doi.org/10.4324/9780203520574>
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE.

- Duckworth, E. (2006). *The having of wonderful ideas: And other essays on teaching and learning* (3rd ed.). Teachers College Press.
- Feuerstein, R., Rand, Y., Hoffman, M. B., & Miller, R. (1980). *Instrumental enrichment: An intervention program for cognitive modifiability*. University Park Press.
- Klibanoff, R. S., Levine, S. C., Huttenlocher, J., Vasilyeva, M., & Hedges, L. V. (2006). Preschool children's mathematical competence: Effects of a purposeful play intervention. *Journal of Research on Educational Effectiveness*, 1(1), 1–24.
- Lillard, A. S. (2017). *Montessori: The science behind the genius* (3rd ed.). Oxford University Press.
- Lillard, A. S., & Heise, M. J. (2016). Removing supplementary materials from Montessori classrooms changed child outcomes. *Journal of Montessori Research*, 2(1), 16–26. <https://doi.org/10.17161/jomr.v2i1.5678>
- Lillard, A. S., Heise, M. J., Richey, E. M., Tong, X., Hart, A., & Bray, P. M. (2017). Montessori preschool elevates and equalizes child outcomes: A longitudinal study. *Frontiers in Psychology*, 8, Article 1783. <https://doi.org/10.3389/fpsyg.2017.01783>
- Marshall, C. (2017). Montessori education: A review of the evidence base. *npj Science of Learning*, 2, Article 11. <https://doi.org/10.1038/s41539-017-0012-7>
- Montessori, M. (1967). *The absorbent mind*. Delta Books. (Original work published 1949)
- Murayama, K., Pékary, Z., & Suzuki, A. (2016). Extrinsic motivation matters! Extrinsic motivation tinges the association between intrinsic motivation and hand grip strength in adolescents. *Frontiers in Psychology*, 7, 275.
- Piaget, J. (1954). *The construction of reality in the child*. Basic Books.
- Sarama, J., & Clements, D. H. (2009). *Early childhood mathematics education research: Learning trajectories for young children*. Routledge.
- Sinclair, N., Arzarello, F., Ferrara, F., & Pimm, D. (2010). *Mathematics and the body: Material structures and the phenomenologies of the classroom*. Cambridge University Press.
- Skemp, R. R. (1989). *Mathematics in the primary school* (3rd ed.). Routledge.
- Stevenson, H. W., Parker, T., Wilkinson, A., Hegion, A., & Fish, E. (1976). Longitudinal study of individual differences in cognitive development and scholastic achievement. *Journal of Educational Psychology*, 68(4), 377–400.
- Tanzania Institute of Education. (2016). *Curriculum and syllabus for pre-primary education in Tanzania*. Ministry of Education, Science and Technology.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press.