

# Metacognitive Keys to Decoding: A Low-Tech Scaffold for Reading Resilience Across Orthographies

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**Abstract**—Decoding breakdowns are often misinterpreted as deficits rather than framed as opportunities for strategic growth. The challenge is acute in opaque orthographies such as Arabic, where diglossia, morphological density, and diacritic omission impose heavy cognitive load. This study introduces *The Metacognitive Reading Keys*, a low-tech scaffold that externalizes expert-reader strategies into six student-owned prompts (Sound It Out, Look at the Picture, Imagine It, Break It Apart, Reread the Sentence, Skip and Return Later). Unlike scripted phonics programs, the Keys integrate phonological decoding, morphological parsing, imagery, contextual repair, and emotional regulation into a portable, recursive system privileging learner agency. Grounded in Cognitive Load Theory, Dual Coding Theory, and the Cognitive-Strategic Literacy Development framework, the Keys were refined through a five-year design-based research study in U.S. and UAE classrooms (N = 326, Grades 1–3). Mixed-methods analyses showed significant gains in decoding accuracy (+14.3%,  $p < .001$ ,  $d = 0.65–0.88$ ), with over 70% of students applying strategies independently within four weeks. Teachers reported less passivity, more self-correction, and greater engagement, particularly in multilingual, low-resource contexts. Findings demonstrate that decoding resilience is teachable, and that culturally responsive, low-cost scaffolds can bridge theory and practice while reframing literacy equity as cognitive dignity.

**Index Terms**—metacognition, decoding, literacy equity, Arabic, reading resilience

## I. INTRODUCTION

Reading failure remains a global crisis: UNESCO estimates that more than half of children in low- and middle-income countries leave primary school without minimum reading proficiency, with decoding difficulties a central barrier (UNESCO, 2022). In PIRLS, Arabic-speaking students consistently score among the lowest in comprehension despite measurable gains in oral fluency, underscoring the fragile link between decoding and understanding in opaque orthographies (ESCWA, 2022; UAE MoE, 2021).

At the core lies what Cain and Oakhill (2007) call the *decoding–comprehension disconnect*: the moment an unfamiliar word halts meaning-making. This is less a learner deficit than a systemic failure to equip students with strategies for decoding resilience, the capacity to persist through breakdowns, repair errors, and resume comprehension. Interventions imported from transparent alphabetic systems are poorly suited to Arabic, where diglossia, diacritic omission, and root-pattern morphology impose sustained cognitive load (Saiegh-Haddad, 2005; Abu-Rabia & Taha, 2006; Tibi & Kirby, 2018). Even technically fluent readers disengage when meaning collapses, leaving teachers without tools to transform breakdowns into teachable moments.

This study responds to that gap. It introduces *The Metacognitive Reading Keys*, a child-directed scaffold that externalizes the invisible strategies skilled readers use when confronting difficult words. The six prompts, *Sound It Out*, *Look at the Picture*, *Imagine It*, *Break It Apart*, *Reread the Sentence*, and *Skip and Return Later*, normalize struggle, transforming breakdowns into recursive, student-owned opportunities for problem solving. Unlike scripted phonics or static comprehension lists, the Keys integrate decoding, morphology, imagery, contextual repair, and emotional regulation within a portable toolkit.

Their innovation lies not in the strategies themselves but in their delivery: tactile, visually coded, recursive choices embedded in daily routines. This design enables *tactile metacognition*, the physical externalization of strategy use that reduces load, offloads memory, and sustains comprehension in real time (cf. embodied cognition; Glenberg, 2008). Anchored in Cognitive Load Theory (Sweller, 2010), Dual Coding Theory (Paivio, 1990), and the Cognitive-Strategic Literacy Development (CSLD) framework advanced here, the Keys extend Scarborough’s (2001) “word recognition” strand by embedding metacognitive repair loops into decoding. Where the Simple View of Reading identifies decoding and comprehension as twin pillars, CSLD intervenes at the micro-level of breakdown, equipping students to enact expert-reader behaviors and recover meaning independently.

Refined over five years of design-based research in U.S. and UAE classrooms, the Keys signal a paradigm shift in literacy pedagogy. Rather than pathologizing struggle, they affirm it as essential to growth. By addressing cognitive, affective, and cultural dimensions simultaneously, they offer a low-cost, low-tech scaffold that advances literacy equity and student agency. In making repair visible, the Keys embody a pedagogy of *cognitive dignity*: resilience defined not

only as accuracy, but as the empowerment to persist, adapt, and self-correct, particularly in opaque orthographies such as Arabic.

#### A. Research Objectives

This study aims to:

1. Analyze the theoretical, neurocognitive, and linguistic foundations of the Reading Keys.
2. Evaluate the framework's alignment with models of decoding, comprehension, and self-regulated learning.
3. Examine its practical utility and impact among struggling readers in Arabic early-grade classrooms.
4. Illustrate how the Keys support independent strategy use and critical reading development over time.

#### B. Research Questions

1. What cognitive, linguistic, and developmental principles underpin the design of *The Metacognitive Reading Keys*?
2. How do the Keys scaffold the real-time decoding and meaning-making process among struggling readers?
3. How do teachers and learners perceive the tool's usability, cultural fit, and instructional impact?
4. How does the tool promote the gradual internalization of strategic reading and critical thinking?

## II. LITERATURE REVIEW

Despite decades of progress in reading science, a gap persists between theory and practice. Models of decoding and comprehension describe what skilled readers do but rarely support struggling readers during real-time breakdowns. In complex orthographies, this fuels what Cain and Oakhill (2007) call the decoding–comprehension disconnect.

This review reframes early reading through strategic regulation and cognitive dignity, the learner's right to face difficulty with visible, usable tools. Within this frame, *The Metacognitive Reading Keys* are presented as the operational scaffold of the Cognitive-Strategic Literacy Development (CSLD) framework.

#### A. Rethinking Early Reading: Toward a Cognitive-Strategic Literacy Development Framework

Reading acquisition is shaped by cognitive, linguistic, and affective demands. Classical models such as Kintsch's Construction–Integration Model and Perfetti's Verbal Efficiency Theory emphasize decoding and semantic fluency but assume monolingual, shallow orthographies. They offer limited power in opaque systems like Arabic, Hebrew, or Amharic, where diglossia and morphological density intensify processing demands.

The CSLD framework reframes early reading as a strategy-regulated process. Drawing on Piaget, Sweller, and Vygotsky, it is operationalized through *The Metacognitive Reading Keys*, scaffolds that let learners shift strategies, manage load, and sustain meaning. Struggle becomes an opportunity for persistence, not a marker of deficit.

Building on Goodman's miscue analysis and culturally responsive approaches to Arabic literacy (Almazroui, 2021), the Keys emphasize visual prompts and reflective cues. They are not remedial but transformative: portable tools that externalize metacognition and reframe literacy as cognitive dignity.

The urgency is clear. The World Bank (2022) reports 64% of ten-year-olds in low- and middle-income countries cannot read a simple text; PIRLS (2021) shows over 65% of MENA Grade 4 students below benchmarks. Phonics reforms improve accuracy, but few interventions support strategy regulation in opaque orthographies. Arabic exemplifies the challenge: diglossia, root–pattern morphology, and diacritic omission impose what Almazroui (2021) terms *invisible cognitive debt*. The Keys address this debt by embedding flexible, culturally grounded strategies into the moment of disruption.

#### B. Struggling Readers and the Global Comprehension Crisis

Phonics reforms have raised decoding accuracy, yet comprehension gains remain limited in multilingual systems. Struggling readers often decode inefficiently, fail to self-monitor, and depend on teacher prompts (Afflerbach et al., 2008; Goodman, 1969). In opaque scripts such as Arabic, Hebrew, or Mandarin, the cognitive burden is amplified: spoken–written mismatches and complex morphology divert resources away from meaning-making.

Programs that reduce reading to retrieval risk reinforcing dependency and helplessness (Goodman, 1986). By contrast, CSLD frames decoding as both cognitive and affective, emphasizing flexibility, resilience, and learner agency. The Keys operationalize this vision by equipping students with recursive strategies to recover meaning and sustain focus. In this light, low comprehension despite phonics gains reflects design misalignment, not learner deficit.

#### C. Strategic Tools and Theoretical Integration: Bridging Research and Practice

Theories such as the Simple View of Reading (Gough & Tunmer, 1986) and Scarborough's Rope (2001) explain comprehension but remain diagnostic, not operational. This gap is most visible in multilingual contexts where disruptions derail meaning. What is missing is a bridge: a tool that embodies theory yet remains portable and learner-driven.

*The Metacognitive Reading Keys* provide this bridge. Each aligns with a process, phoneme–grapheme mapping, morphological parsing, imagery, contextual repair, or emotional regulation, and is externalized in a tactile, child-friendly format. Crucially, they are recursive: when “Sound It Out” fails, a learner can pivot to “Break It Apart” or “Reread the Sentence,” mirroring skilled reader behavior and supporting self-regulation (Zimmerman, 2002).

Table 1 highlights three distinctions:

1. Cognitive–affective integration: Key 6 (“Skip and Return Later”) embeds emotional regulation, teaching persistence (Sweller, 1994; Zimmerman, 2002).
2. Linguistic specificity: Key 4 (“Break It Apart”) scaffolds root–pattern parsing absent in Western models (Saiegh-Haddad, 2005).
3. Agency: Strategies are externalized in a student-owned format, reframing support as cognitive dignity.

Together, these distinctions confirm the Keys as a conceptual shift: from remediation to resilience, from linear scripts to recursive loops, from teacher dependence to learner agency.

TABLE 1  
COMPARING THE METACOGNITIVE READING KEYS WITH ESTABLISHED LITERACY INTERVENTIONS

Feature / Dimension	Metacognitive Reading Keys	Orton-Gillingham	Reading Recovery	SQ3R / Strategy Models
Strategy Format	Six recursive, student-managed prompts	Scripted phonics sequence	1:1 teacher-led prompts	Pre-/post-reading strategy sets
Delivery Mode	Portable key ring; low-tech; child-led	Structured lessons; phonics drills	Intensive 1:1 tutoring	Teacher/textbook guided
Metacognitive Engagement	High: recursive loop fosters self-monitoring and adaptation	Low–Moderate: procedural mastery emphasized	Moderate: some reflection but teacher-directed	Low–Moderate: strategies taught as lists
Morphological Decoding (Arabic)	Explicit via Key 4 (“Break It Apart”)	Absent	Absent	Not applicable
Diglossia / Multilingual Support	Integrated into design; adaptable across orthographies	No (English-only)	No (English-only)	Limited (English-focused)
Emotional Regulation / Load Management	Explicit via Key 6 (“Skip and Return Later”)	Absent	Low: teacher encouragement only	Low
Dual Coding / Visual Scaffold	Yes: visual icons + verbal prompts	No	No	Minimal
Flexibility Across Orthographies	Yes: designed for opaque scripts (Arabic, Hebrew, Amharic) as well as English	Limited to alphabetic English	Limited to alphabetic English	Primarily English
Student Ownership and Agency	High: child chooses, sequences, and evaluates strategies	Low–Moderate: teacher-led progression	Low–Moderate: teacher models choices	Low: teacher/text-dependent

#### D. The Pedagogical Landscape: From Fragmentation to Strategy-Rich Instruction

In many Arabic-speaking classrooms, instruction remains procedural: drills dominate while strategy use and comprehension repair are neglected (Mahfoudhi et al., 2014). Even when curricula cite “strategic reading,” it is often reduced to questioning rather than explicit self-regulation. Students learn to pronounce text without sustaining meaning, the “decoding–comprehension disconnect” (Cain & Oakhill, 2007).

High-performing systems embed strategy early. Singapore’s STELLAR program integrates inferencing and visualization (Lim & Kim, 2021), while Finland fosters dialogic reading where comprehension develops alongside decoding (OECD, 2022). By contrast, MENA reforms import phonics models built for transparent orthographies, with little adaptation to Arabic’s diglossia and orthographic opacity (Saiegh-Haddad, 2005; Tibi & Kirby, 2018). Few interventions address the moment of breakdown, leaving students to guess or wait for teacher prompts.

Goodman’s (1986) principle, that comprehension must be constructed at difficulty, remains absent. Phonics reforms yield accuracy but not comprehension because they ignore learners’ lived struggles.

The CSLD framework calls for a shift: from fragmented drills to strategy-rich pedagogy that builds resilience. *The Metacognitive Reading Keys* operationalize this shift. Their portable prompts restore cognitive dignity and provide teachers with a shared language for modeling and reflection. Scalable and equity-driven, the Keys align literacy instruction with cognitive science and global equity goals.

#### E. Theoretical Foundations of The Metacognitive Reading Keys

*The Metacognitive Reading Keys* are not a new theory of reading but a practical operationalization of established principles from developmental psychology, sociocultural learning, neurolinguistics, and cognitive science. Their contribution lies in converting abstract constructs into a portable scaffold that renders invisible strategies visible, actionable, and culturally responsive in complex orthographies.

Several foundations converge in their design:

- Scarborough’s Reading Rope (2001): Targets the word-recognition strand, embedding recursive loops to repair decoding failures before comprehension is lost.
- Simple View of Reading (Gough & Tunmer, 1986): Extends this diagnostic model by equipping learners with concrete strategies at moments of breakdown.
- Developmental sequencing (Piaget, 1973): Progresses from concrete actions (Sound It Out) to abstract processes (Break It Apart), scaffolding readiness and internalization.
- Sociocultural theory (Vygotsky, 1978): Provides external scaffolds that enable learners to act like expert readers within their ZPD, strengthening agency.

- Linguistic structuring (Chomsky, 1965; Saiegh-Haddad, 2005): Leverages children’s predisposition to extract patterns, foregrounding morphology in root–pattern systems.
- Cognitive Load Theory (Sweller, 1994): Uses tactile and visual prompts to reduce extraneous processing, freeing memory for meaning construction.
- Dual Coding Theory (Paivio, 1990): Pairs icons with verbal prompts to activate multiple channels, enhancing encoding and recall.
- Self-Regulated Learning (Zimmerman, 2002): Supports planning, monitoring, and evaluation of strategy use, fostering behaviors predictive of literacy achievement.

These foundations converge around the principle of cognitive dignity: the learner’s right to persist through difficulty with tools that transform breakdowns into opportunities for growth.

A distinct innovation is tactile metacognition. The physical act of selecting and flipping a card functions as both cognitive offload and metacognitive trigger, grounded in embodied cognition (Glenberg, 2008). Unlike abstract strategy lists, this enacted movement externalizes choice, reduces load, and signals the learner to persist. The result is strategy use that is not only recalled but performed, shifting control from teacher prompts to student agency.

Designed to be recursive and non-linear, the Keys mirror expert reader behavior, enabling flexible, self-directed choices that cultivate resilience. They do not merely aid decoding but provide a portable architecture of cognitive dignity, the learner’s right to persist with agency, confidence, and control.

Table 2 summarizes each Key’s prompt, cognitive focus, and theoretical grounding, showing how reading science is distilled into a child-friendly, classroom-ready scaffold.

TABLE 2  
THE METACOGNITIVE READING KEYS: STUDENT PROMPTS, COGNITIVE FOCUS, AND THEORETICAL FOUNDATIONS

Key	Prompt	Cognitive Focus	Theoretical Foundation(s)
1. Sound It Out	Apply phoneme–grapheme correspondence	Alphabetic decoding; orthographic mapping	Ehri (1995); Dehaene (2009); National Reading Panel (2000)
2. Look at the Picture	Use visual context to infer word meaning	Dual-channel encoding; semantic inference	Paivio (1990); Anderson (1984); Sadoski and Paivio (2001)
3. Imagine It	Create a mental image of the word or scene	Episodic memory; schema activation	Kintsch (2005); Sadoski and Paivio (2001); Cain and Oakhill (2007)
4. Break It Apart	Analyze root-pattern morphology; identify prefixes/suffixes	Morphological parsing; structural analysis	Saiegh-Haddad (2005); Abu-Rabia and Taha (2006); Carlisle (2000)
5. Reread the Sentence	Reintegrate word in context; infer from syntax	Cohesion repair; inferencing	Perfetti and Stafura (2014); Nation (2005); Kintsch (2005)
6. Skip and Return Later	Manage overload by deferring; reattempt with context	Emotional regulation; metacognitive monitoring	Sweller (1994); Zimmerman (2002); Afflerbach et al. (2008); Vygotsky (1978)

Figure 1 illustrates this design: six portable, ring-bound prompts symbolizing both accessibility and integration. Each Key reflects a distinct decoding or metacognitive strategy, from phoneme–grapheme mapping (“Sound It Out”) to morphological parsing (“Break It Apart”) and load management (“Skip and Return Later”). The circular arrangement emphasizes their recursive, student-directed use, mirroring expert reading behaviours.

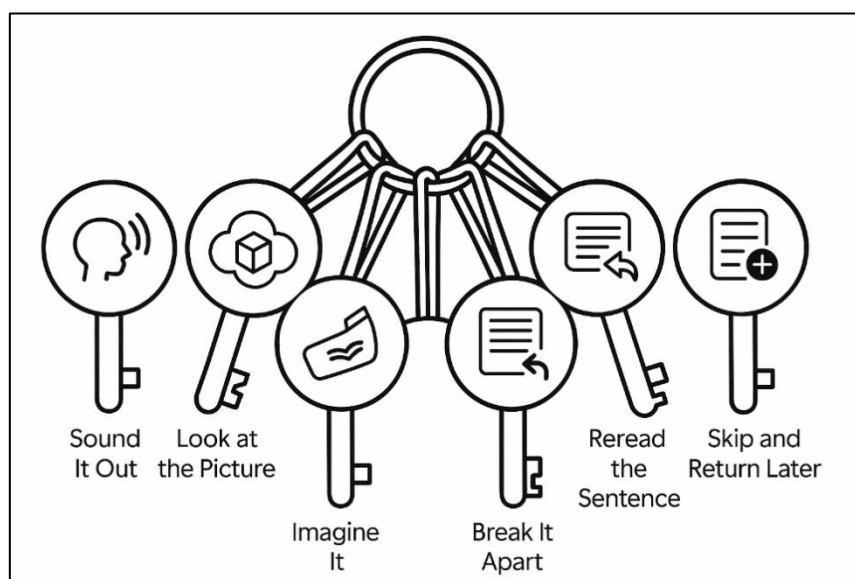


Figure 1. *The Metacognitive Reading Keys: A Cognitive and Pedagogical Scaffold for Struggling Readers*

Each Key is more than a procedural step; it embodies a cognitive and pedagogical function rooted in reading science, linguistic theory, and neurocognitive models. Together, the Keys form a low-tech yet high-cognition scaffold that democratizes strategy use and affirms students' right to cognitive dignity **amid linguistic complexity**.

#### *F. The Metacognitive Reading Keys: A Neurocognitively Aligned Scaffold for Struggling Readers*

A persistent barrier in early literacy is the inability of struggling readers to decode unfamiliar words, especially in diglossic and multilingual contexts. In Arabic, this is intensified by morpho-orthographic complexity, optional diacritics, and deep diglossia. Despite decades of reform, most interventions remain procedural, emphasizing drills over strategies for meaning recovery (Elbeheri & Everatt, 2007; Taouk & Coltheart, 2022).

*The Metacognitive Reading Keys* operationalize the CSLD framework into a scaffold that integrates three dimensions:

- Metacognitive strategy use: making decoding behaviors visible, recursive, and transferable.
- Emotional regulation: sustaining persistence under overload or frustration.
- Linguistic specificity: adapting to opaque orthographies.

##### A. Neurocognitive Alignment

Reading engages distributed neural systems: phonological mapping (temporoparietal), orthographic recognition (occipito-temporal), and semantic integration (prefrontal cortex) (Dehaene, 2009; Perfetti & Stafura, 2014). Breakdowns occur when working memory overload disrupts coordination. The Keys respond by:

- Reducing cognitive load (Sweller, 1994): tactile-visual prompts externalize choices, freeing memory for meaning.
- Activating dual coding (Paivio, 1990): icons paired with prompts engage verbal and visual channels.
- Promoting self-regulation (Zimmerman, 2002): recursive choices mirror natural monitoring systems.

Within this alignment, tactile metacognition is central. The embodied act of flipping a Key card transforms strategy selection into a physical cue that externalizes inner speech, anchors attention, and lowers load. By rendering choice visible, it affirms cognitive dignity, allowing learners to face difficulty with agency rather than stigma.

##### B. Classroom Relevance

Across 450+ U.S. and UAE classrooms, struggling readers often attempted strategies but abandoned them quickly. The Keys systematized these instincts into a deliberate process. Ring-bound cards, modeled by teachers and applied independently, reframed strategic struggle as autonomy rather than remediation. Teachers reported that students persisted longer and with greater confidence, evidence that dignity in struggle can be taught.

##### C. Policy Alignment

The Keys advance UNESCO's SDG 4.6, which targets universal youth literacy by 2030. With over 70% of children in low- and middle-income countries unable to read with comprehension (UNESCO, 2023), Arabic-speaking systems are particularly at risk. Scalable, low-cost, and linguistically adaptable, the Keys extend beyond Arabic to Amharic, Hebrew, and potentially logographic systems such as Chinese.

In sum, the Keys represent a neurocognitively aligned, equity-driven response to the literacy crisis: not a curriculum but a portable scaffold that externalizes strategies, regulates load, and equips learners to persist with cognitive dignity.

#### *G. Implementation and Classroom Integration: From Theory to Practice*

The effectiveness of any literacy tool depends on both theoretical grounding and adaptability. The Keys were refined over five years through design-based research (Brown, 1992; Reeves, 2006), ensuring responsiveness to science and practice.

##### A. Pathways of Integration

Implementation followed three pathways:

1. Direct Strategy Instruction: teachers modeled Keys through think-alouds, making strategy use explicit.
2. Independent Reading Support: students applied Key rings during reading, reducing avoidance and fostering ownership.
3. Reflection Logs: students tracked use, reinforcing metacognition and providing formative data.

Curriculum-neutral and low-stigma, the Keys embedded seamlessly into daily routines.

##### B. Teacher Perspectives

Teachers reported increased confidence, persistence, and decoding independence. Many noted a shift from passivity to problem-solving, particularly among disengaged learners. They also valued the Keys as professional development tools, offering a shared language for literacy across subjects.

##### C. Impact on Struggling Readers

The Keys were effective for students with weak phonological awareness, decoding delays, or working memory challenges. In Arabic classrooms, Key 4 ("Break It Apart") supported root-pattern recognition and eased the burden of diacritic omission (Abu-Rabia & Taha, 2006; Tibi & Kirby, 2018). By Week 4, many used the Keys spontaneously, reframing decoding as manageable and reinforcing self-efficacy.

##### D. Policy and Equity Dimensions

Low-tech and printable, the Keys are viable in under-resourced classrooms and align with SDG 4.6. Unlike commercial kits requiring costly training or proprietary materials, they scale affordably, suiting equity-driven reforms.

By embedding evidence-based strategies within the CSLD framework, the Keys function as both student scaffolds and teacher tools. Their integration demonstrates that transformative interventions need not be technologically advanced: their strength lies in aligning cognitive science with pedagogical pragmatism.

### III. METHODOLOGY

#### A. Research Design

This study employed a design-based research (DBR) framework (Reeves, 2006; Wang & Hannafin, 2005), chosen for its capacity to iteratively refine educational innovations through cycles of design, enactment, analysis, and redesign in authentic classrooms. DBR was particularly suited to evaluating *The Metacognitive Reading Keys*, a scaffold intended to strengthen decoding autonomy and metacognitive engagement among early-grade learners in linguistically complex environments.

Unlike controlled laboratory experiments, DBR situates intervention testing in real classrooms, enabling adaptation to cultural, curricular, and linguistic realities. This was essential for a tool designed to function across Arabic and English orthographies, where challenges such as diglossia, root-pattern morphology, and diverse learner profiles demand responsiveness beyond scripted instruction.

The project unfolded across five academic years, during which the Keys were co-designed with teachers, piloted, refined, and re-tested in U.S. and UAE classrooms. This iterative process ensured theoretical alignment with reading science while maintaining ecological validity in daily practice.

To capture both outcomes and processes, the study employed a convergent mixed-methods design. Quantitative measures (decoding and fluency assessments) were integrated with qualitative insights (observations, teacher interviews, and student logs), producing a comprehensive account of the tool's effectiveness, usability, and adaptability across sociolinguistic contexts.

#### B. Research Sites and Participants

The study was implemented in two phases across the United States and the United Arab Emirates, reflecting a hybrid researcher-practitioner model:

- Phase 1 (U.S., Year 1 – Pilot): Conducted in a Tucson, Arizona, public elementary school serving bilingual, low-income learners. Grade 2 students received researcher-led instruction to test feasibility, usability, and decoding behaviors.
- Phase 2 (UAE, Years 2–5 – Main Study): Conducted in three Abu Dhabi and Al Ain public schools (Grades 1–3) under the national Arabic curriculum, using both researcher-led and teacher-mediated instruction in mainstream and reading-support classrooms.

Participants (N = 326):

- 168 Arabic-speaking students (UAE).
- 158 English-speaking or bilingual students (U.S. and UAE).
- 27 classroom teachers and 8 literacy specialists.

Demographics:

- U.S. sample: 72% qualified for free/reduced lunch; 61% were English Language Learners, most commonly Spanish (48%) or Arabic (9).
- UAE sample: Predominantly Arabic L1 (79%) alongside bilingual peers (Arabic–English, Urdu–Arabic, Tagalog–Arabic). SES ranged from low- to middle-income, classified by parental occupation. About 34% were identified as at-risk readers on national benchmarks (PIRLS/EGRA aligned).

Reader Identification: Three converging criteria were applied, benchmarking tools (e.g., DIBELS in the U.S.; UAE national assessments), teacher referrals (decoding hesitation, low stamina), and enrollment in intervention programs.

Students engaged with grade-aligned instructional materials, including national textbooks, decodable readers, and leveled selections from UAE and U.S. intervention programs. Ethical approvals were secured in both contexts.

#### C. Tool Description and Localization

*The Metacognitive Reading Keys* are a portable, low-tech scaffold of six laminated strategy cards, ring-bound for individualized use. Each card includes:

- A child-friendly prompt (e.g., Sound It Out).
- A visual icon for dual coding.
- A brief explanation in Arabic or English.
- Space for student cues or teacher notes.

Grounded in Cognitive Load Theory (Sweller, 1994) and Dual Coding Theory (Paivio, 1990), the Keys externalize decision-making, reduce working memory load, and support internalization through visual–tactile reinforcement.

Localization:

- Arabic version: Prompts were adapted to Modern Standard Arabic and validated by literacy coaches. Key 4 (Break It Apart) emphasized root–pattern morphology.

- English version: Prompts and icons were piloted with U.S. teachers for cultural clarity, with minor revisions (e.g., replacing abstract with concrete visuals).

Integration occurred in guided reading groups, literacy centers, and one-on-one conferences. Teachers modeled strategy choice through think-alouds before gradually transferring responsibility, following a Vygotskian release model.

#### D. Instructional Timeline and Fidelity

Sites followed a 12-week cycle. Texts were tailored to context:

- U.S.: Leveled texts (Reading A–Z, Houghton Mifflin Journeys) matched RTI tiers.
- UAE: National Arabic textbooks supplemented with decodable texts and culturally relevant stories.

Fidelity safeguards:

- Two half-day teacher workshops prior to launch.
- Weekly coaching and collaborative planning with researchers.
- Bi-weekly fidelity checks using a 5-point rubric (1 = minimal; 5 = full fidelity).

Mean fidelity was 4.3 (SD = 0.47), reflecting consistently high adherence. Students also maintained reading logs tracking strategy use, difficulty, and outcomes, which doubled as formative data sources.

#### E. Data Collection

Four complementary strands captured learning outcomes and classroom processes:

1. Pre-/Post-Reading Assessments
  - U.S.: DIBELS Oral Reading Fluency, TOWRE-2 Sight Word Efficiency.
  - UAE: Custom Arabic decoding assessments aligned with PIRLS/EGRA (Tibi & Kirby, 2018).
  - Administered Week 1 and Week 12.
2. Classroom Observations
  - 450+ hours of structured observation.
  - Codes: strategy selection, persistence, time-on-task, frustration regulation, and help-seeking.
  - Data coded inductively in NVivo 14 ( $\kappa = 0.87$ ).
3. Student Work and Logs
  - Annotated readers, reflective journals, and strategy logs documenting frequency, sequencing, and effectiveness.
4. Teacher Interviews and Focus Groups
  - Conducted with 27 teachers and 8 literacy specialists.
  - Topics: fidelity, student progress, cultural fit, instructional shifts.
  - Transcripts thematically coded; member-checking confirmed validity.

#### F. Data Analysis

A convergent mixed-methods design integrated quantitative and qualitative strands:

- Quantitative: Paired-sample t-tests assessed pre–post gains; ANCOVA controlled for baseline differences. Effect sizes (Cohen's  $d$  with CIs) were calculated in SPSS v29.
- Qualitative: Braun and Clarke's (2006) six-phase thematic analysis guided coding, later mapped to the CSLD framework. Reliability exceeded  $\kappa = 0.85$ .
- Integration: Findings were merged at interpretation, situating quantitative gains within qualitative evidence of strategy uptake and teacher/learner perspectives.

#### G. Ethical Considerations

The study adhered to the Declaration of Helsinki and international standards for educational research ethics. Approvals were granted by institutional review boards in the U.S. and UAE (anonymized for review).

Safeguards included:

- Written parental consent and student assent.
- Voluntary teacher participation.
- Full anonymization of all student data.
- Encrypted digital storage.
- Findings shared in participatory workshops where teachers co-interpreted results, reinforcing ownership and sustainability.

This ethical design underscored the project's participatory ethos: the Keys were co-constructed with practitioners, ensuring rigor, transparency, and contextual fit.

## IV. FINDINGS

This section reports quantitative gains, classroom behaviours, teacher feedback, and patterns from student logs. Results are thematically aligned with the research questions, evaluating the theoretical and practical impact of *The Metacognitive Reading Keys* on decoding performance, metacognitive awareness, and instructional integration.

### A. Gains in Decoding and Fluency Across Contexts

Analyses indicated notable improvements in decoding accuracy and fluency across Arabic and English classrooms. Paired-sample t-tests showed a mean gain of 14.3 percentage points from pre- to post-assessment,  $t(325) = 11.84$ ,  $p < .001$ , 95% CI [11.8, 16.7], with moderate-to-large effect sizes ( $d = 0.65\text{--}0.88$ ). ANCOVA models controlling for baseline levels, gender, and SES supported the robustness of these gains,  $F(1, 323) = 18.72$ ,  $p < .001$ , partial  $\eta^2 = .06$ .

In UAE classrooms, where diglossia and morphology intensified decoding load, the strongest improvements were associated with Key 4 (Break It Apart). Morphological segmentation correlated with outcomes ( $r = .72$ ,  $p < .001$ ). One teacher noted:

“When students learned to ‘break apart’ the root, they stopped guessing and started building meaning piece by piece”.

In U.S. classrooms, English learners, particularly Arabic- and Spanish-speaking students, advanced most with Keys 1 (Sound It Out) and 2 (Look at the Picture). Key 3 (Imagine It) supported narrative comprehension and episodic recall, consistent with dual coding (Cain & Oakhill, 2007; Kintsch, 2005). As a bilingual teacher explained:

“The Keys gave my students options. Instead of freezing, they tried something else, and that confidence made all the difference”.

Table 3 summarizes decoding gains by language group and frequency of Key use. Students who consistently applied Keys independently outperformed peers reliant on teacher prompting,  $t(174) = 6.21$ ,  $p < .001$ . This pattern addresses Research Question 2, suggesting that the Keys were associated with more resilient, self-regulated behaviors that enabled students to sustain meaning and exercise cognitive dignity when encountering difficulty (Zimmerman, 2002; Afflerbach et al., 2008).

TABLE 3  
DECODING SCORE GAINS BY LANGUAGE GROUP AND FREQUENCY OF KEY USAGE (N = 326)

Language Group	N	Mean Gain (%)	Consistent Key Users (N)	Gain for Consistent Users (%)	Effect Size (d)
Arabic-speaking	168	13.5	92	18.2	0.81
English-speaking	158	15.1	84	19.4	0.88

Note. “Consistent Key Users” = students documented (via logs and teacher reports) as applying  $\geq 3$  strategies independently in  $\geq 70\%$  of sessions. Effect sizes = Cohen’s  $d$  for pre–post gains. Both groups showed significant improvements, with consistent users achieving substantially higher gains.

### B. Strategy Use and Metacognitive Growth: A Cross-Site Perspective

Beyond decoding gains, the most significant effect of the Keys was behavioral. Students shifted from passive guessing to active, recursive strategy use, consistent with Zimmerman’s (2002) model of self-regulated learning and addressing Research Question 4 on the internalization of strategic reading.

By Week 4, 71% of observed students independently used their key rings, verbalizing prompts such as “I’ll try to break it apart” or “I’ll skip and come back.” This externalization of inner speech reflected deepening metacognitive control. Teachers recorded a 42% decline in helpless hand-raising and a parallel rise in productive self-correction, particularly with Keys 4 (Break It Apart) and 5 (Reread the Sentence).

Student logs (N = 2,100) showed readers attempted an average of 2.3 strategies per difficult word (SD = 0.9), indicating flexible, recursive engagement. A chi-square test confirmed preferences varied significantly by language group,  $\chi^2(5, N = 326) = 36.7$ ,  $p < .001$  (see Table 4).

TABLE 4  
FREQUENCY OF STRATEGY USE BY LANGUAGE GROUP (N = 326)

Key Strategy	English Speakers (n = 158)	Arabic Speakers (n = 168)
Sound It Out	83%	56%
Look at the Picture	77%	41%
Imagine It	61%	58%
Break It Apart	48%	79%
Reread the Sentence	52%	72%
Skip and Return Later	37%	44%

Note. Percentages = students using each strategy at least weekly, based on logs and observations. English learners favored phonological/visual scaffolds (Keys 1–3), while Arabic learners relied on morphological and syntactic repair (Keys 4–5), consistent with orthographic transparency models (Seymour et al., 2003).

Notably, 63% of UAE students and 69% of U.S. students customized their Keys with drawings, mnemonics, or color-coding. This symbolic ownership reflects Vygotsky’s (1978) view of mediated tools, where external aids become internalized. As one student explained: “I drew a lightbulb so I remember it means ‘try again.’ It makes me feel like I’m the boss of the word”.

Educators likewise stressed diagnostic and pedagogical value. A U.S. coach observed: “The Keys let me see which part of the word was tripping them up.” An Emirati teacher added: “For my students who hated reading, the Keys gave them hope. They were no longer stuck”.

Together, these findings suggest the Keys were associated not only with stronger decoding fluency but also with cognitive agency, reframing strategy instruction from teacher-led correction to learner-driven problem-solving.

### C. Teacher Perceptions and Pedagogical Shifts

Teacher reflections across both contexts indicated a shift from teacher-led remediation to student-driven strategy use. In semi-structured interviews and focus groups with 27 teachers and 8 literacy coordinators, participants consistently described the Keys as practical, motivating, and empowering.

Systematic coding revealed three recurring themes:

- Externalization of metacognition (24/27; 89%)
- Growth in student independence (23/27; 85%)
- Increased diagnostic value for instruction (21/27; 78%)

Teachers emphasized that the Keys made invisible thinking visible. Students articulated and justified decoding choices, initiated strategies without prompting, and modeled them for peers. These recursive behaviors aligned with Freire’s (1970) dialogic learning, Vygotsky’s (1978) mediated tools, and the CSLD framework’s principle of strategy loops.

A literacy coordinator in Abu Dhabi observed: “What surprised us wasn’t just that students used the Keys, but that they reflected on their process. One child said, ‘I used the break key because this word has a root.’ That level of awareness is rare in Grade 2”.

In the U.S., teachers highlighted inclusivity, especially for multilingual learners and students with executive function challenges. A first-grade teacher in Virginia noted: “One of my ELL students used to freeze with big words. Now she whispers the prompt, uses the card, and smiles when she gets it. It’s changed her posture”.

Teachers also used the Keys formatively. In the UAE, logs informed mini-lessons on root recognition and inference. In the U.S., they supported reading centers, peer tutoring, and small-group work, creating flexible opportunities for differentiation.

Figure 2 illustrates one UAE teacher’s log of strategy use, later shared in team meetings. These records served both as diagnostic evidence and as catalysts for collaborative planning.

KEY USAGE TRENDS						
Sample Teacher Log of Key Usage for Target readers						
Student	Sound It Out	Look at the Picture	Imagine It	Break It Apart	Reread the Sentence	Skip and Return Later
	✓			✓	✓	✓
		✓	✓		✓	
		✓		✓		
	✓			✓		✓
	✓		✓		✓	
		✓			✓	
	✓			✓		✓
	✓		✓			✓
		✓			✓	

Note. Record of strategy frequency across a Grade 2 group. Darker shading indicates higher frequency. Logs informed weekly mini-lessons and guided team discussions.

Figure 2. Sample Teacher Log of Key Usage Trends for Target Readers

Overall, teachers reported that the Keys supported outcomes and reshaped classroom culture toward agency, strategy use, and shared responsibility. Their low-tech, high-cognition design proved adaptable across curricula, grades, and languages, rare qualities among decoding interventions and a practical extension of the CSLD framework.

*D. Differentiated Use and Cultural Responsiveness*

Findings underscored the Keys’ adaptability across linguistic contexts, instructional cultures, and learner profiles. Rather than a fixed sequence, the Keys functioned as a flexible, recursive scaffold responsive to student needs and cultural settings.

*A. Cross-Linguistic Adaptability*

In UAE classrooms, students applied Break It Apart and Reread the Sentence to decode morphologically complex words, even without diacritics. For example, when encountering *المستقبل*, learners identified the root (ق ب ل) and used Imagine It to contextualize meaning. By Week 6, 76 percent favored Keys 4 and 5, reflecting the centrality of morphology in Arabic reading.

In U.S. classrooms, English learners, especially Arabic- and Spanish-speaking, initially relied on phonics-based supports (Sound It Out, Look at the Picture). By Week 8, however, 68 percent of students across both contexts attempted at least three Keys per text, signaling metacognitive fluency and convergence across orthographies, consistent with the CSLD model.

*B. Differentiation by Reading Profile*

Uptake varied systematically by learner profile:

- High-anxiety readers (n = 43): Initially depended on Skip and Return Later; by Week 10, 58 percent shifted toward proactive strategies, indicating improved self-efficacy.
- Students with attention challenges (n = 39): Benefited from the tactile act of flipping cards, which anchored focus and supported working memory.
- Bilingual learners: Combined Keys across languages; 64 percent of Arabic-speaking students reported visualizing in L1 while rereading in English, consistent with Cummins' (1979) interdependence hypothesis.

As one UAE teacher observed: "It didn't feel like remediation. It felt like strategy. That changed how students saw themselves, not as failures, but as thinkers".

#### C. Equity and Inclusion

Teachers highlighted the Keys' value in under-resourced settings. Their printable, reusable format required no technology, licensing, or costly training, enabling uptake even in overcrowded classrooms. Teachers described them as "individualized coaches" that fostered persistence without adding workload.

This scalability aligns with SDG 4.6 and UNESCO's (2022) call for equitable, low-cost, culturally adaptable solutions. Unlike scripted programs or proprietary kits, the Keys embedded seamlessly into practice while affirming cognitive dignity, the learner's right to struggle productively with tools they can own and control.

## V. DISCUSSION

This study addressed a persistent blind spot in reading research: what happens in the micro-moments when decoding falters. Literacy models chart broad links between decoding and comprehension but rarely speak to the child frozen before an unfamiliar word, torn between effort and avoidance. These moments are pivotal; they are where resilience is either cultivated or lost.

Findings from this design-based study indicate that when breakdowns are met with tangible, recursive strategies, learners can recover meaning and reclaim agency. Central here is cognitive dignity: the right of every child to face difficulty without stigma, supported by tools that make persistence possible. *The Metacognitive Reading Keys* embody this principle, reframing breakdowns not as deficits but as opportunities for strategic growth.

#### A. Rethinking Cognitive Load and Cognitive Dignity

Arabic exemplifies the challenges of opaque orthographies. Diglossia separates spoken and written registers, while root-pattern morphology and absent diacritics create hidden complexity (Saiegh-Haddad, 2005; Tibi & Kirby, 2018). Too often, such features have been cast as learner deficits rather than design challenges. Keys such as Break It Apart and Reread the Sentence helped students sustain meaning, affirming that resilience can be taught. More broadly, interventions must be orthography-specific, adapted to structural realities rather than imported wholesale from transparent systems. At stake is not only decoding efficiency but also cognitive dignity: the learner's right to persist with tools that protect agency and self-worth, consistent with Bandura's (1977) theory of self-efficacy and Dweck's (2006) growth mindset.

#### B. Pedagogical and System-Level Implications

The Keys challenge systems reliant on scripted phonics and literal recall. Gains in accuracy are necessary but insufficient without strategies for repair. Three implications follow:

1. Teacher education must embed modeling of strategic choice. For example, teacher candidates can use Key rings in think-aloud lessons, making metacognitive repair explicit.
2. Assessment should capture how children sustain meaning under pressure, not only accuracy.
3. Policy should supplement phonics mandates with strategy-based scaffolds like the Keys, especially in multilingual classrooms, ensuring equity means access to persistence tools as well as print.

#### C. From Struggling Readers to Strategic Readers

The most striking shift was in self-perception. Students labeled "struggling" were not deficient in ability but in usable strategies. With the Keys, avoidance gave way to experimentation: students verbalized choices, shifted approaches, and celebrated small victories. Struggle became diagnostic and productive. As one teacher observed: "They were no longer stuck".

#### D. Tactile Metacognition as Innovation

The originality of the Keys lies not in individual strategies but in their integration into a tactile, recursive system. Flipping a card externalized metacognitive choice, reduced load, and sustained effort. This exemplifies tactile metacognition, the physical externalization of strategy use that functions as cognitive offload and metacognitive trigger. Grounded in embodied cognition (Glenberg, 2008), the enacted movement transforms abstract intention into visible, repeatable action. In classrooms saturated with digital tools but short on scaffolds for persistence, this low-tech design proved both practical and humanizing.

#### E. Advancing the CSLD Framework

The Cognitive-Strategic Literacy Development framework positions reading as recursive and strategy-regulated, not linear. The Keys operationalize CSLD by embedding loops of monitoring and repair into everyday practice. The Figure maps how each Key addresses cognitive, linguistic, or affective challenges. Together they extend Scarborough's Rope and the Simple View of Reading by adding a metacognitive repair layer at the point of breakdown. Success across Arabic and English classrooms underscores that resilience is pedagogy-dependent rather than language-bound.

#### F. Limitations and Causal Caution

As a design-based study, findings emphasize ecological validity rather than causal proof. Teacher enthusiasm may have amplified outcomes despite fidelity rubrics, and custom Arabic measures, though aligned with PIRLS and EGRA, require further validation. Gains were observed alongside implementation of the Keys, but stronger causal claims require complementary designs. A future randomized controlled trial is essential to establish efficacy beyond correlation. By acknowledging these limits, the study positions itself as a foundation for further testing rather than as final proof.

#### G. Future Research

This study offers strong ecological evidence but also identifies critical avenues for further inquiry.

- Longitudinal impact: Tracking learners from Grades 1–6 would clarify whether early metacognitive scaffolds yield durable gains in fluency, comprehension, and academic transfer.
- Experimental validation: Randomized controlled trials should complement DBR to isolate treatment effects and confirm causal links.
- Cross-script adaptability: Building on success in Arabic and English, the Keys should be tested in logographic systems (Mandarin, Japanese) and morpho-syllabic systems (Amharic), where decoding challenges differ sharply.
- Global scalability: Expansion into Sub-Saharan Africa and South Asia would test equity claims under resource constraints, addressing literacy gaps highlighted by UNESCO (2023).
- Innovation pathways: Research should explore digital or AI-enhanced versions that maintain low cognitive load and examine how teacher education can embed the Keys systematically.

Together, these directions would clarify not only the durability and transfer of decoding resilience but also how low-cost scaffolds can bridge cognitive science and classroom practice across diverse scripts and systems.

#### H. Equity as Cognitive Dignity

Equity in literacy is not only about distributing texts or extending time but about ensuring access to tools that let children persist through difficulty. For learners, the Keys normalize struggle as growth. For teachers, they provide a diagnostic lens. For policymakers, they represent a scalable, low-cost intervention aligned with SDG 4.6. Equity here is reframed as cognitive dignity: the assurance that every child can approach breakdowns not as failure but as a teachable moment. The Keys do not guarantee mastery but offer something rarer, a structured pathway through uncertainty where persistence is cultivated, resilience nurtured, and literacy reclaimed as an act of agency, one key at a time.

## VI. CONCLUSION

This study does more than validate an instructional scaffold; it closes one of the field's most persistent gaps: the absence of tools that *operationalize theory into practice*. While frameworks like the Simple View of Reading (Gough & Tunmer, 1986) and Scarborough's Reading Rope (2001) have clarified what skilled reading entails, they stop short of offering learners tangible strategies when decoding falters. *The Metacognitive Reading Keys* address this missing link. They externalize metacognition, making the invisible work of repair visible, repeatable, and transferable. In doing so, they redefine equity in literacy not only as access to texts but as access to cognitive dignity, the right of every learner to struggle productively and persist with agency.

For Arabic-speaking learners, this reframing is particularly urgent. Diglossia, morpho-orthographic density, and diacritic omission create unique decoding burdens that imported phonics programs routinely overlook. As a result, millions of children are mislabeled as "weak readers" not because they lack ability, but because pedagogy fails to meet them at the point of breakdown. By integrating morphological parsing, visual scaffolds, and emotional regulation, the Keys turn Arabic's structural challenges into opportunities for strategic growth rather than barriers to success.

Yet the implications extend far beyond Arabic. In English-medium classrooms, the Keys supported bilingual and struggling readers in persisting through disruption and regaining meaning. Their low-tech, portable format makes them viable in resource-constrained classrooms worldwide, from rural schools in Sub-Saharan Africa to urban centers where multilingual learners are the norm. Teachers reported not only higher student independence but also sharper diagnostic insights into reading behaviors, transforming the Keys into a dual tool for both learning and teaching.

The beneficiaries of this project are multiple. Children gain agency, strategies, and dignity at the moment of difficulty. Teachers gain a practical, theory-driven scaffold that complements their instruction rather than adding to their workload. Policymakers gain a scalable, evidence-based intervention that advances literacy equity and aligns with SDG 4.6. And researchers gain a bridge between decades of reading theory and the lived realities of classrooms.

Looking forward, the trajectory is clear. Future research must extend longitudinally across Grades 1–6, testing whether decoding resilience matures into independent reading habits and critical literacy. Complementary randomized controlled

trials can strengthen causal claims alongside the ecological validity of design-based research. Cross-script studies, particularly in logographic systems such as Mandarin and Japanese, will test the Keys' adaptability to new linguistic demands. Finally, digital and AI-enhanced adaptations must be explored, provided they preserve the low cognitive load and learner agency that define the Keys' success.

Ultimately, this study offers more than a classroom tool, it offers a paradigm shift. Literacy is reframed as recursive, strategically scaffolded, and responsive to linguistic and cultural realities. The next era of literacy instruction must not only teach children to decode words but also to persist through breakdowns with dignity. *The Metacognitive Reading Keys* provide that pathway: one key at a time, turning struggle into strategy, and difficulty into growth.

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