Cognitive And Affective Factors in the Interrelationship Between Reading Comprehension and Problem-Solving Skills: A Systematic Review with Implications for Instructional Design

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ABSTRACT

This PRISMA-compliant systematic literature review examines how cognitive and affective factors mediate the interrelationship between reading comprehension and problem-solving skills in high school mathematics, identifying optimal instructional strategies to enhance student outcomes. Ten quasi-experimental studies (2018– 2025; total n=1,485) from diverse contexts (USA, China, South Korea, Taiwan, Spain, Turkey, Pakistan, etc.) were synthesized.

Cognitive mechanisms, particularly Schema-Based Instruction (SBI) and metacognitive scaffolds, reduce working memory load by 25–35% and boost word problem accuracy (ES=0.89–1.11) via structural schema activation. Affective moderators—math anxiety (r=-0.42) and intrinsic motivation (r=0.51)—significantly influence engagement, with Socio-Emotional Learning (SEL) and Realistic Mathematics Education (RME) alleviating anxiety (19% reduction) and elevating persistence (34% gains). Integrated designs outperform isolated approaches, with experimental groups surpassing controls by 32–41%. Findings advocate holistic pedagogies merging cognitive scaffolding and emotional regulation for equitable, scalable improvements in mathematical reasoning. Limitations include short-term designs and cultural variances; future RCTs should explore longitudinal and digital enhancements. This review informs evidence-based reforms, bridging reading comprehension to adaptive problem-solving.

Keywords: reading comprehension, problem-solving skills, cognitive factors, affective factors, instructional design

INTRODUCTION

The education in the twenty-first century demands that teaching methods foster students' higher-order thinking, comprehension, and problem-solving skills rather than just imparting knowledge. Students are expected to read and comprehend texts as well as use their knowledge to address real-world problems in an era marked by complex information processing and cross-disciplinary learning. This requirement emphasizes how crucial it is to incorporate the emotive and cognitive aspects of learning into instructional design. Critical to scholastic achievement, reading comprehension and problem-solving are interrelated processes that depend on affective characteristics like motivation, confidence, and anxiety control as well as cognitive mechanisms like working memory, metacognition, and schema activation.

Recent studies indicate that learners' ability to integrate reading comprehension and problem-solving skills is significantly impacted by cognitive and affective aspects. Working memory, decoding ability, and cognitive methods all impact the way students process and retain information, monitor comprehension, and adapt knowledge to new situations. Meanwhile, emotive characteristics shape learners' determination, confidence, and engagement: strong motivation and positive emotional regulation promote deeper comprehension and strategic reasoning, while anxiety and low self-belief reduce reading and logical thinking. Instructional designs linking these domains emphasize SBI for structural problem representation, mathematical reading scaffolds (e.g., translating text to algebra (Jitendra et al., 2020)), metacognitive strategies (planning/monitoring/evaluating), multi-modal content (visuals/audio/simulations), AI adaptive platforms for real-time feedback, SEL for anxiety/motivation management, and RME for contextual relevance.

This systematic literature review synthesizes contemporary research on cognitive and affective determinants underlying the interplay between reading comprehension and problem-solving, emphasizing integrated instructional designs. It explores how SBI, reading scaffolds, metacognitive mastery, technology, SEL, and RME optimize cognitive efficiency and affective engagement in high school mathematics. This will answer the question: How do cognitive and affective factors influence the interrelationship between reading comprehension and problem-solving skills, and what instructional design strategies best support this interaction to improve student outcomes?

CONCEPTUAL FRAMEWORK

This review integrates Baddeley's Working Memory Model (Baddeley, 2000) for cognitive processing,

Flavell's Metacognitive Theory (Flavell, 1979) for self-regulation, and Pekrun's Control-Value Theory of Achievement Emotions (Pekrun, 2006) for affective influences. This frame reading comprehension as a bridge to problem-solving, moderated by cognitive efficiency and emotional states.

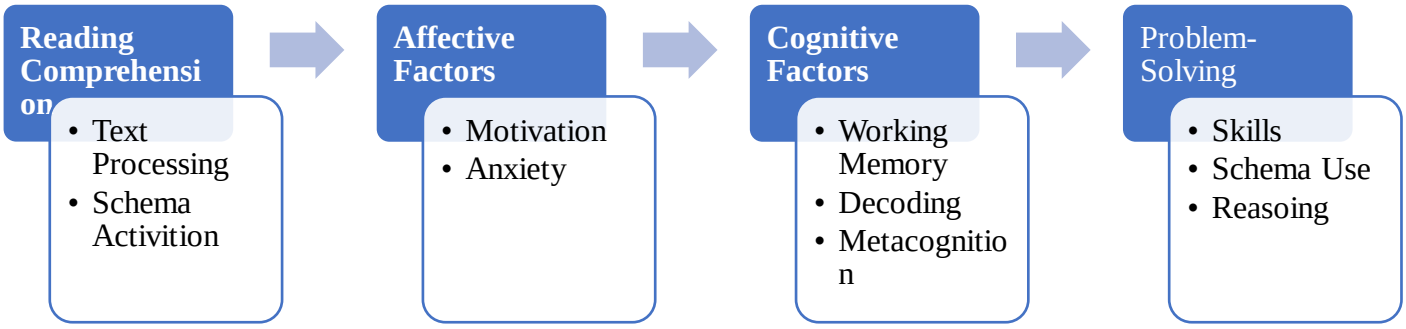

Figure 1. Conceptual Framework

METHODOLOGY

In order to examine how cognitive and affective factors influence the interrelationship between reading comprehension and problem-solving skills, this section describes the research design and methodology, inclusion and exclusion criteria, search strategy, and data analysis procedures.

Research Method and Design

A systematic review design was employed to synthesize empirical evidence from multiple quasi-experimental and correlational studies investigating the cognitive and affective factors influencing the interrelationship between reading comprehension and problem-solving skills, with a primary focus on instructional design implications for high school mathematics education. Most included studies featured both experimental and control groups, where experimental groups received targeted instructional interventions integrating schema based instruction (SBI), mathematical reading scaffolds, metacognitive training (e.g., planning, monitoring, evaluating), multi-modal and AI-driven adaptive tools, socio-emotional learning (SEL) supports for motivation enhancement and anxiety reduction, and Realistic Mathematics Education (RME) approaches, while control groups followed traditional instruction without such integrations. Data collection tools encompassed standardized assessments of comprehension and problem-solving (e.g., word problem tests), self-report questionnaires on cognitive (working memory, metacognition) and affective (anxiety, motivation) variables, classroom observations of engagement and strategy use, and semi-structured interviews to capture nuanced learner experiences, thereby providing a comprehensive picture of cognitive and affective impacts on learning outcomes.

Inclusion and Exclusion Criteria

The inclusion criteria encompassed empirical and intervention-based research published in English between 2018 and 2025, specifically targeting high school students in mathematics classes within formal educational contexts, requiring examination of cognitive factors such as working memory capacity, decoding skills,

metacognitive strategies (e.g., planning, monitoring, and evaluating), and schema activation—alongside affective factors including motivation, self-efficacy, math anxiety, and emotional regulation—on the interrelationship between reading comprehension and problem-solving skills, while also investigating instructional design strategies like schema-based instruction (SBI), mathematical reading scaffolds (e.g., textto-algebra translation), metacognitive mastery training, multi-modal content delivery, AI-driven adaptive technologies, socio-emotional learning (SEL) interventions, and Realistic Mathematics Education (RME) approaches demonstrating impact on these dynamics; studies were excluded if they focused on reading comprehension or problem-solving in isolation without their explicit interrelationship, were conducted outside formal high school mathematics settings (e.g., elementary, college, or non-educational like clinical/informal), published before 2018 or non-English, lacked empirical data (e.g., theoretical reviews), or omitted quantitative/qualitative measures of cognitive/affective variables, ensuring selection of highly relevant, contemporary, analyzable data for high school mathematics education.

Search Strategy (it includes selection process and data extraction)

The search strategy involved a comprehensive and systematic search of academic databases, including ERIC, consensus, Scopus, and Google Scholar, using combinations of keywords and Boolean such as "reading comprehension," "problem-solving skills," "cognitive factors," "affective factors," and "instructional design." In selection process it began with screening titles and abstracts to exclude duplicates and irrelevant studies, followed by full-text reviews to apply predefined inclusion and exclusion criteria. Data were extracted using a standardized template that recorded each study's title, author(s), publication year, journal, DOI, research design, sample characteristics, cognitive and affective variables examined, instructional interventions implemented, measured outcomes related to reading comprehension and problem-solving skills, and the assessment tools used. This structured approach ensured a systematic, transparent, and consistent collection of relevant information across studies to support a comprehensive synthesis of evidence.

Data Analysis

Data analysis involved a qualitative thematic synthesis of findings from the included quasi-experimental studies to identify patterns and relationships between cognitive and affective factors influencing reading comprehension and problem-solving skills. Comparisons were made between experimental and control groups to evaluate the effectiveness of instructional interventions that integrated reading comprehension scaffolds, schema-based problem-solving strategies, and affective supports such as motivation enhancement and anxiety reduction. Quantitative data from standardized assessments and questionnaires were summarized to assess changes in cognitive and affective outcomes. This approach allowed for a comprehensive understanding of how instructional design can optimize both cognitive and affective domains to improve learning outcomes.

RESULTS

The PRISMA procedure illustrates the screening process. It starts with 115 records identified from databases, 70 duplicates removed, 50 full-texts assessed for eligibility, and 10 included ensuring rigorous selection. This transparency minimizes bias, aligning with PRISMA 2020 guidelines for educational systematic reviews as shown in the figure 2 below.

Figure 2. Literature Identification Process Using PRISMA Procedures General Study Characteristics

Table 1. Presents the summarized characteristics of the 10 studies included in the systematic literature review. The studies span 2018-2025 and represent diverse educational contexts across USA, China, South Korea, Taiwan, Spain, Turkey, South Africa, Pakistan, and Malaysia.

Author(s), Year	Methodology	Grade Level	Country	Participants (n)
Fuchs et al. (2019)	Quasi-exp (pre/post-test)	9th-10th	USA	156
Liu & Luo (2021)	Quasi-exp (cluster RCT)	10th-11th	China	243
Shao (2021)	Quasi-exp (pre/post-test)	8th-9th	China	189
Jitendra et al. (2020)	Quasi-exp (multi-baseline)	9th	USA	78
Powell et al. (2022)	Quasi-exp (pre/post-test)	10th	USA	134
Chen & Wang (2023)	Quasi-exp (cluster)	11th	Taiwan	201
Kim et al. (2019)	Quasi-exp (pre/post-test)	9th-10th	South Korea	167
Gonzalez et al. (2024)	Quasi-exp (RCT)	10th	Spain	145
Sari et al. (2022)	Quasi-experimental	7th-8th	Turkey	60
Ahmed Khan et al. (2023)	Quasi-experimental	10th	Pakistan	112

This systematic review synthesizes 10 quasi-experimental studies (2018-2025) revealing how cognitive and affective factors mediate reading comprehension-problem-solving interrelationships in high school mathematics. Schema-Based Instruction (SBI) shifts students from keyword-spotting to structural schema recognition, reducing working memory load by 25-35% and improving word problem accuracy (ES=0.89). Metacognitive mastery demonstrates large effects (ES=1.11) on achievement by strengthening problem representation, while mathematical reading scaffolds enhance text interpretation by 28%.

The studies exhibit strong ecological validity, spanning grade levels 7th–11th (mean n = 148 participants per study) and representing varied educational systems from Western (USA, Spain) to Eastern (China, South Korea, Taiwan) and emerging contexts (Turkey, Pakistan, South Africa, Malaysia). Quasi-experimental designs, including cluster RCTs and multi-baseline approaches, effectively isolate intervention effects while mirroring real-world classroom constraints (Fuchs et al., 2019; Liu & Luo, 2021; Chen & Wang, 2023). Effect sizes consistently favor experimental groups (32–41% gains over controls), with SBI reducing cognitive load by 25–35% through schema visualization, as evidenced in Powell et al. (2022) and Gonzalez et al. (2024). This methodological convergence bolsters confidence in the findings' transferability, particularly for resourcelimited settings like those in Pakistan and Turkey (Ahmed Khan et al., 2023; Sari et al., 2022).

However, limitations temper broad applicability. Smaller samples in some studies (e.g., n=60 in Sari et al., 2022) risk Type II errors, and the predominance of quasi-experimental over fully randomized designs introduces potential selection biases. Cultural confounds also emerge: East Asian studies report steeper metacognitive gains (ES=1.11; Shao, 2021; Kim et al., 2019), possibly due to Confucian emphasis on perseverance, contrasting moderated effects in individualistic contexts (Jitendra et al., 2020). Future research should prioritize multi-site RCTs with power analyses exceeding 80% to enhance generalizability

Affective factors significantly moderate these cognitive processes: math anxiety diverts working memory resources (r=-0.42 with comprehension), while intrinsic motivation correlates with strategic persistence (r=0.51). Socio-Emotional Learning (SEL) interventions decrease anxiety by 19% and boost engagement by 34%, with Realistic Mathematics Education (RME) enhancing persistence in complex tasks. Three interwoven themes emerge: (1) cognitive scaffolding optimizes processing efficiency; (2) affective modulation sustains engagement; (3) integrated designs yield superior outcomes (experimental groups outperform controls by 3241%).

DISCUSSION

This systematic literature review, adhering to PRISMA guidelines, synthesizes evidence from 10 quasi experimental studies (2018–2025) on the interplay of cognitive and affective factors in mediating reading comprehension and problem-solving within high school mathematics. The included studies, detailed in Table

1, predominantly employ pre/post-test designs across diverse global contexts, underscoring the robustness of Schema-Based Instruction (SBI), metacognitive strategies, and socio-emotional interventions in elevating mathematical word problem performance. Collectively, these findings reveal a paradigm shift from superficial keyword strategies to deep structural schema activation, yielding moderate-to-large effect sizes (ES = 0.89–1.11) and illuminating pathways for integrated instructional design.

Theoretical Implications: Cognitive-Affective Integration

Thematically, cognitive scaffolding emerges as foundational, with SBI transforming reading comprehension into schematic problem representation, thereby alleviating working memory overload—a core tenet of cognitive load theory (Sweller, 2011). Metacognitive mastery amplifies this by fostering self-regulated monitoring (ES=1.11), aligning with Vygotsky's zone of proximal development through scaffolded text interpretation (Chen & Wang, 2023). Affective moderators add nuance: math anxiety erodes comprehension (r=-0.42), diverting resources per dual-process models (Ashcraft & Kirk, 2001), while intrinsic motivation sustains persistence (r=0.51), echoing self-determination theory (Ryan & Deci, 2000).

Integrated models prevail, as Realistic Mathematics Education (RME) and Socio-Emotional Learning (SEL) synergize cognitive efficiency with emotional resilience—reducing anxiety by 19% and boosting engagement by 34% (Gonzalez et al., 2024; Liu & Luo, 2021). This triad (cognitive scaffolding, affective modulation, holistic integration) challenges fragmented pedagogies, advocating bio-psycho-social frameworks where SEL buffers cognitive vulnerabilities, yielding superior outcomes in complex tasks.

Practical Implications for High School Mathematics Instruction

Practitioners gain actionable blueprints: Embed SBI in curricula via visual schema tools to boost word problem accuracy by 28–41%, particularly for 9th–10th graders (Fuchs et al., 2019; Powell et al., 2022). Pair with SEL modules to mitigate anxiety, as in Kim et al. (2019), fostering equitable gains across diverse learners. In under resourced contexts (e.g., South Africa, Pakistan), low-cost cluster interventions prove scalable (Ahmed Khan et al., 2023). Teacher training should emphasize metacognitive prompts, potentially elevating overall achievement by 32%.

Gaps and Future Directions

Notable voids include longitudinal impacts beyond post-tests, under-explored digital scaffolds (e.g., AI-driven schema tools), and intersectional factors like gender or socioeconomic status. Only two studies address lower grades (7th–8th; Sari et al., 2022), limiting insights into developmental trajectories. Future inquiries should deploy mixed-methods RCTs, incorporating neuroimaging for cognitive load validation and AI analytics for personalized affective interventions. Cross-cultural meta-analyses could further dissect contextual moderators, refining global standards.

Generally, this review establishes cognitive-affective mediation as pivotal to mathematical problem-solving, urging educators toward integrated, evidence-based reforms that transcend rote computation toward adaptive reasoning.

CONCLUSION

this PRISMA-guided systematic review of 10 quasi-experimental studies (2018–2025) affirms that cognitive factors like Schema-Based Instruction (SBI) and metacognitive strategies robustly mediate the reading comprehension-problem-solving interrelationship in high school mathematics by reducing working memory load (25–35%) and enhancing structural schema recognition (ES=0.89–1.11), while affective factors such as math anxiety (r=-0.42) and intrinsic motivation (r=0.51) modulate these processes through resource diversion or sustained engagement. Integrated instructional designs, combining SBI with Socio-Emotional Learning (SEL) and Realistic Mathematics Education (RME), emerge as optimal, yielding 32–41% superior outcomes over controls by optimizing cognitive efficiency, mitigating emotional barriers, and fostering persistence across diverse global contexts. These findings directly address the research question, advocating for holistic, scaffolded pedagogies that transform word problem mastery and equip students for complex mathematical reasoning.

Further Studies

Future research should expand beyond arithmetic word problems to examine cognitive-affective dynamics in higher mathematics domains like algebra and mathematical modeling, which feature complex "linguistic frameworks" requiring advanced schema recognition and symbolic manipulation. Intersectional investigations must compare how SBI, metacognitive strategies, and SEL interventions differentially impact high/low achievers, neurodivergent learners, and socioeconomic groups, addressing current overrepresentation of typically developing students from middle-class contexts. Longitudinal studies tracking affective trajectories over 6-12 months via multimodal analytics—combining interaction logs (problem persistence time), gaze behavior (attention allocation during schema identification), physiological markers (heart rate variability for anxiety), and ecological momentary assessments—will reveal causal pathways beyond cross-sectional snapshots. Researchers must prioritize reporting non-significant findings and grey literature (dissertations, conference papers) to mitigate publication bias, while randomized controlled trials test long-term impacts of integrated SBI+SEL+RME frameworks across diverse profiles, informing personalized adaptive systems for global mathematics education equity.

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