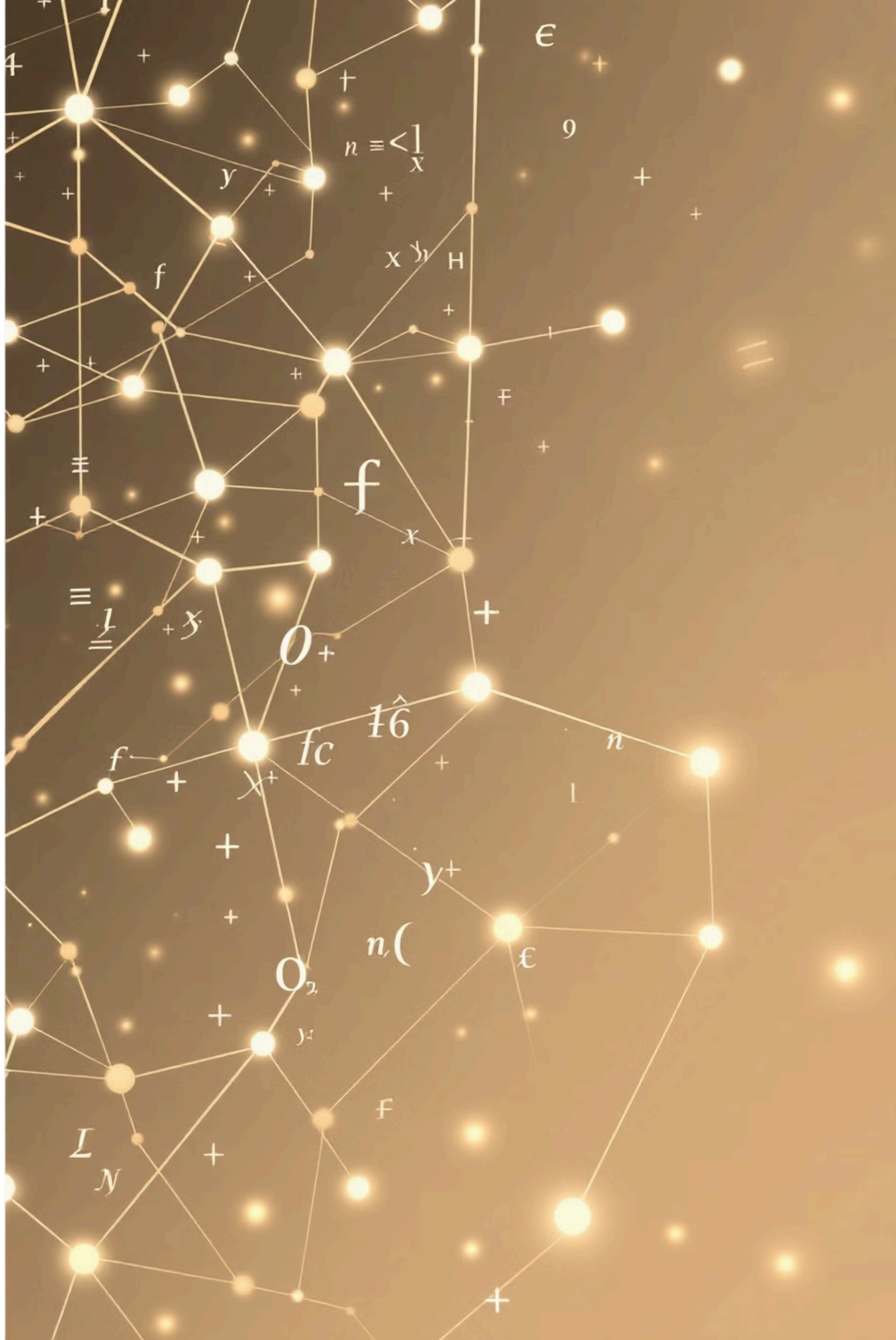
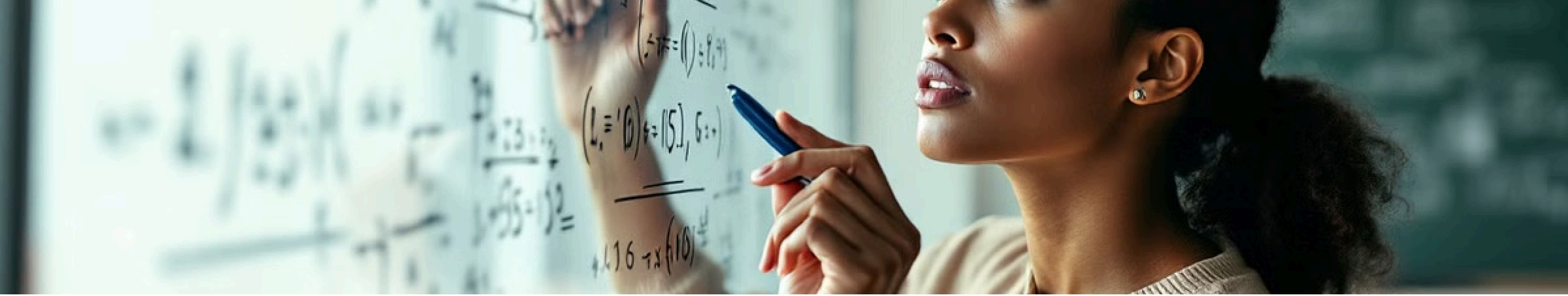
Mathematics Education and Creativity: Influencing Cognitive Arousal, Self-Efficacy and Motivation- Meta-Analysis Article

Swartz, H., & Fuchs, A. (2025). Mathematics Education and Creativity - Influencing Cognitive Arousal, Self-Efficacy and Motivation- Meta-Analysis Article. *Gaia, 1*(1) - (the Educational Spectrum), 38 – 48

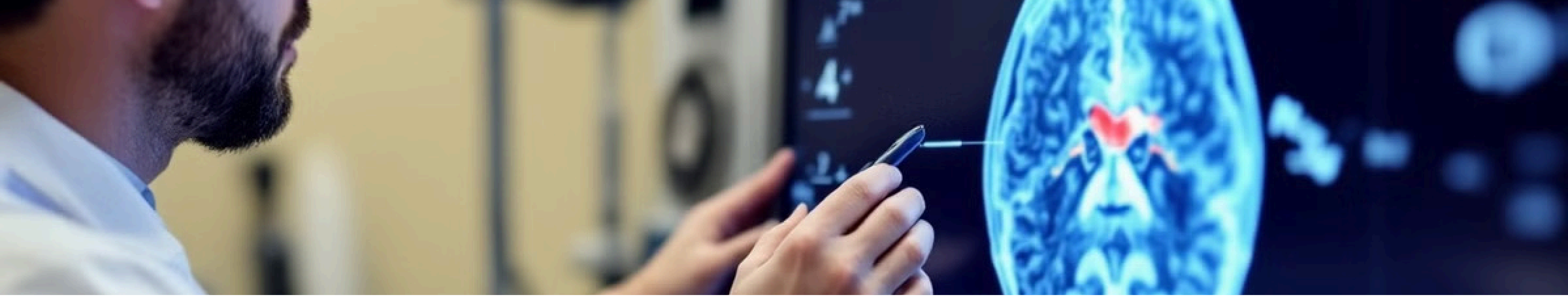




Mathematics Education and Creativity

This presentation explores the cognitive distinctions between mathematical problem-solving and problem-posing processes. While problem-solving primarily engages visuospatial working memory, fact retrieval, and procedural execution, problem-posing activates distinct neural pathways involving metacognition, conceptual integration, and dorsolateral prefrontal networks.

Our synthesis of neuroimaging, behavioral, and educational research reveals how these complementary processes influence cognitive arousal, self-efficacy, and motivation in mathematics education through different mechanisms. These findings suggest that pedagogical approaches should intentionally develop both skill sets to optimize mathematical reasoning abilities and enhance student engagement.



Foundational Cognitive Processes in Mathematical Reasoning

Triple-Code Theory

Mathematical cognition operates through three neuroanatomical circuits: a verbal system for arithmetic facts (left perisylvian areas), a quantitative magnitude system (bilateral intraparietal sulci), and a visuospatial system for complex calculation (right parietal regions).

Prefrontal Cortex Engagement

These systems interface with prefrontal cortical regions responsible for working memory, cognitive flexibility, and goal maintenance—functions critical for solving and posing tasks but utilized differently across contexts.

Adaptive Cognitive Functions

The dynamic interactions between core number representation systems, memory networks, and executive control mechanisms demonstrate the adaptability of cognitive functions in mathematical reasoning.

Cognitive Mechanisms in Problem-Solving

Visuospatial Working Memory

Facilitates retention of intermediate calculation steps and visual-spatial number representations. Essential for solving planning tasks and mental arithmetic, especially when employing counting strategies.

Neural Network Activation

Activates bilateral networks encompassing prefrontal, parietal, and inferior temporal regions. Left inferior frontal gyrus (IFG) regions associate with arithmetic fact retrieval.

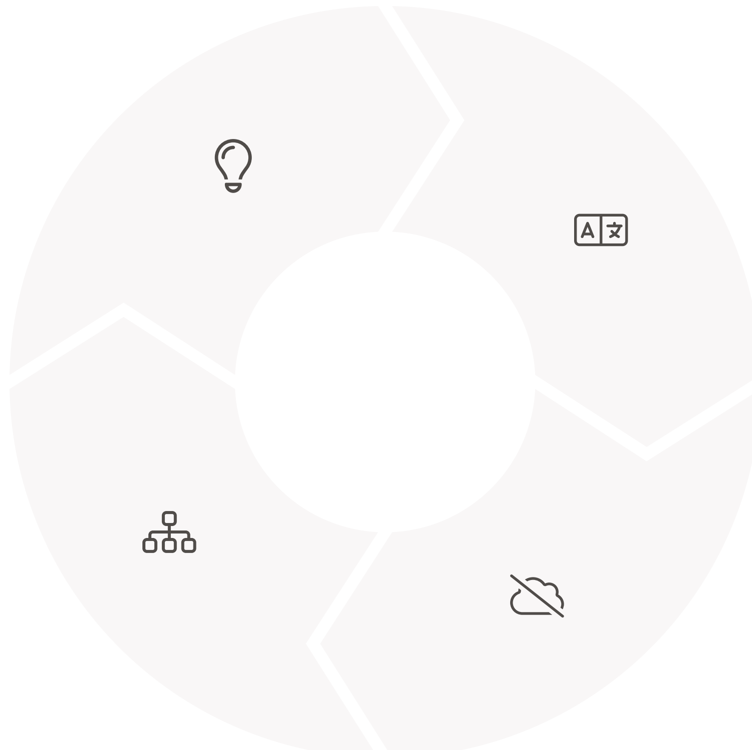
Cognitive Flexibility

Enables strategy adaptation and generation of multiple solution pathways. Particularly necessary for open-ended problems where solution strategies aren't immediately obvious.

Knowledge Integration

Combines conceptual understanding (knowing why) with procedural knowledge (knowing how). Prior knowledge significantly affects problem encoding and solution processes.

Cognitive Mechanisms in Problem-Posing



Metacognition

Engages reflective thinking and concept organization, enhancing self-regulation and deep learning

Language Processing

Requires linguistic structuring and verbal ability to articulate mathematical ideas clearly

Hierarchical Goal Setting

Activates dorsolateral prefrontal networks governing abstract reasoning and task design

Conceptual Reasoning

Involves deconstructing mathematical concepts and bridging numerical operations with linguistic expressions

Unlike problem-solving, which primarily activates procedural memory and numerical cognition, question-writing demands higher-order cognitive functions. Studies indicate that writing about mathematics strengthens concept organization, abstraction, and anticipation of problem-solving pathways.

Neural Distinctions Between Solving and Posing

Problem-Solving Neural Activity

Activates left inferior frontal gyrus (IFG) regions associated with arithmetic fact retrieval. Engages bilateral prefrontal and parietal networks essential for arithmetic processing and logical reasoning.

Positive math attitudes enhance left IFG activation during fact retrieval, suggesting motivational factors modulate working memory efficiency in solving tasks.

Problem-Posing Neural Activity

Recruits dorsolateral prefrontal networks governing abstract reasoning and task design. Activates regions associated with language processing and metacognitive monitoring.

Engages neural pathways involved in creative thinking and conceptual integration, distinct from those used in procedural execution.

Motivational and Attitudinal Factors

Self-Actualization

Creative problem-posing fosters sense of achievement

Self-Efficacy

Mastery of both skills builds mathematical confidence

Positive Attitudes

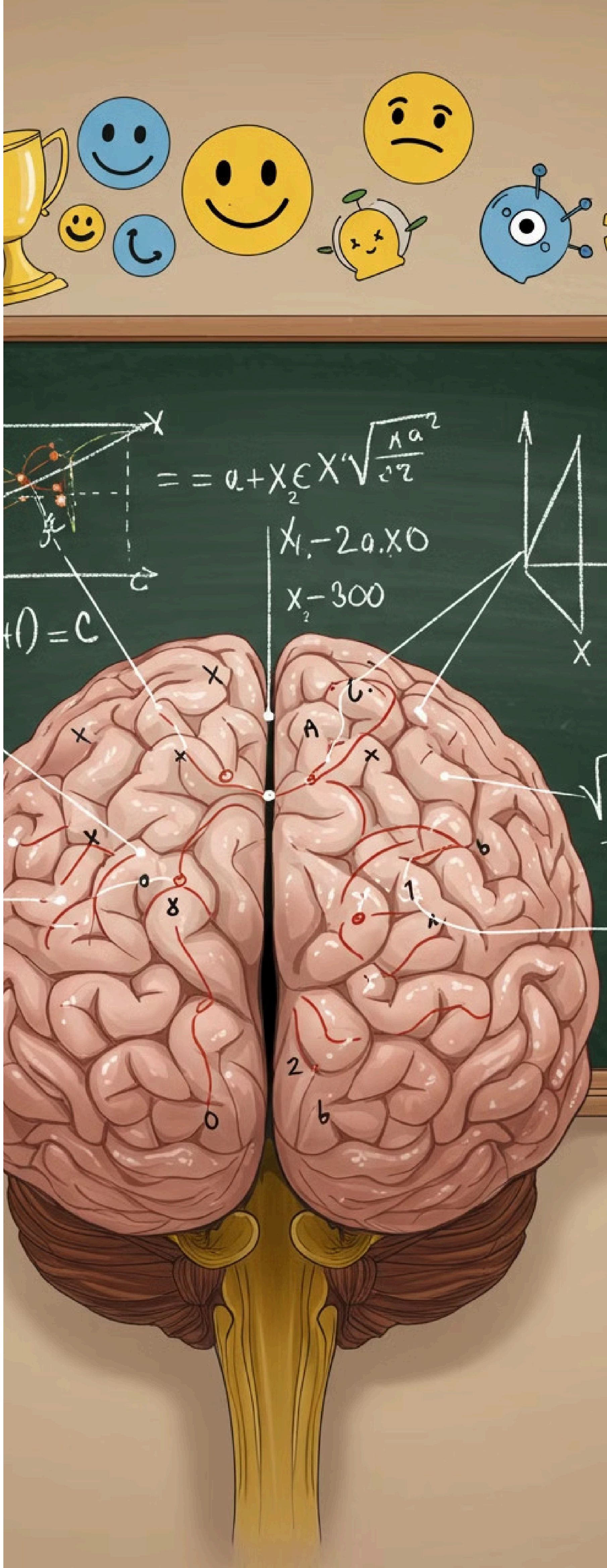
Enhanced hippocampal engagement supports efficient memory strategies

Growth Mindset

Fosters cognitive development through enhanced cortico-striatal dynamics

Research demonstrates that positive math attitudes are associated with increased activation in the left inferior frontal gyrus (IFG) during arithmetic problem-solving, particularly for children with lower math skills. This enhanced IFG activation reflects greater effort in fact retrieval and is linked to improved multiplication skills over time.

Longitudinally, motivation and learning strategies, rather than intelligence, predict growth in math achievement. Students with growth mindsets persist longer in retrieving partially encoded facts rather than defaulting to compensatory counting strategies.



Educational Implications

Balanced Approach

Integrate both problem-solving and question-writing activities to optimize learning outcomes. While problem-solving develops procedural fluency and spatial reasoning, writing enhances metacognition and conceptual understanding.

Reflective Practice

Incorporate problem-solving activities with reflective writing to reinforce metacognitive skills. This combination helps students organize and consolidate their mathematical thinking while developing their ability to communicate ideas coherently.

Cognitive Flexibility Development

Provide structured opportunities for students to explore multiple problem-solving approaches. This develops adaptability and creative thinking in mathematical contexts.

Working Memory Support

Address working memory constraints in instruction, particularly for students with learning disabilities. Incorporate spatial cognition training and visuospatial working memory exercises.

Future Research Directions

Developmental Trajectories

Investigate how problem-solving and problem-posing abilities develop across age groups

Instructional Design

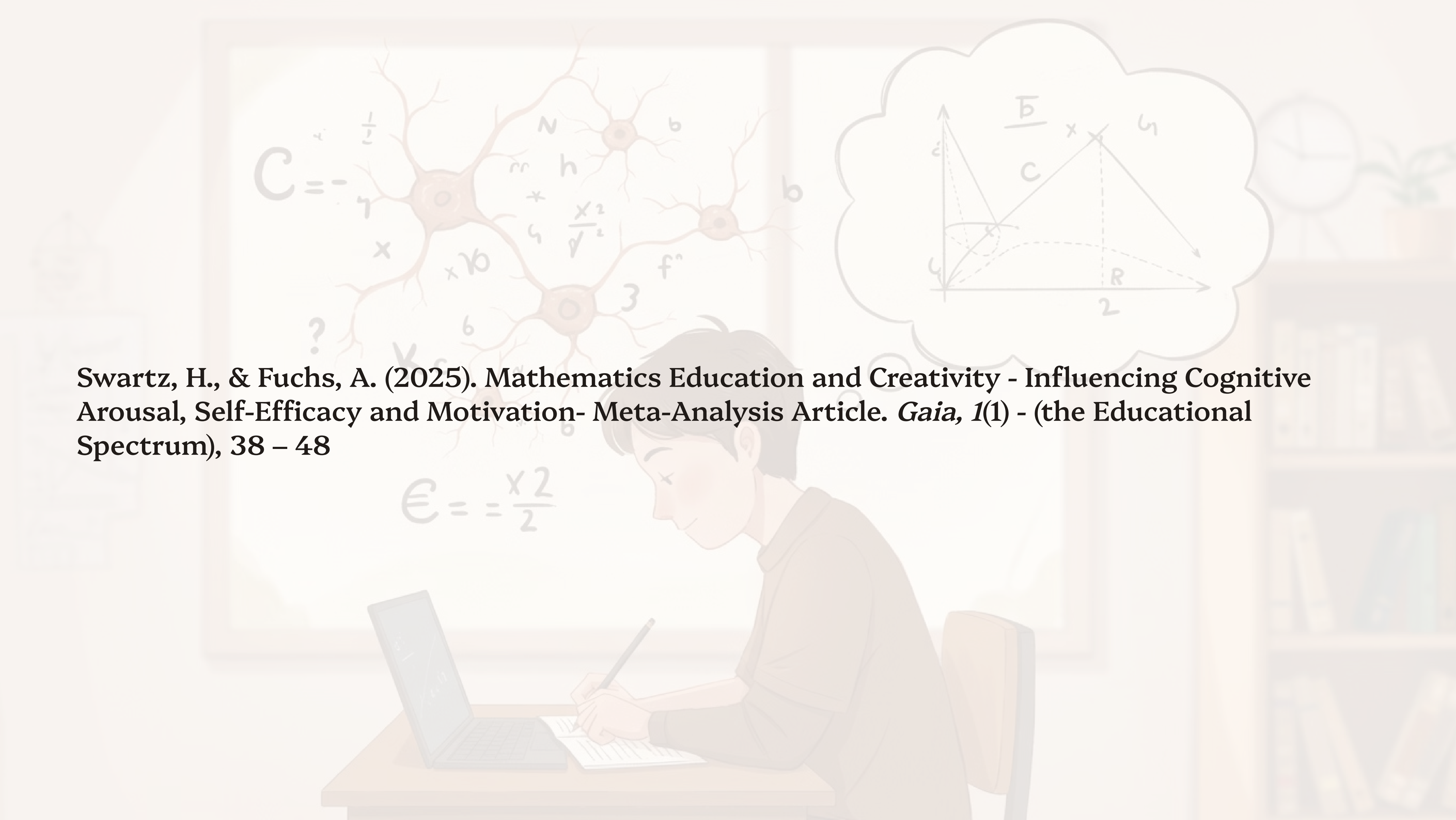
Develop specific strategies to systematically build both cognitive skill sets

Individual Differences

Explore effectiveness across diverse student populations and learning styles

Future research should explore how specific instructional strategies can be designed to systematically develop both cognitive skill sets, particularly in diverse student populations and across different developmental stages.

Such work would not only advance our understanding of mathematical cognition but also provide practical guidance for enhancing mathematics education in ways that promote both competence and creativity. Optimal learning environments should create conditions where learners can move flexibly between these complementary modes of cognition.



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