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Reconstruction of a Neuroscience Based Learning Model to Enhance Elementary School Students' Learning Engagement

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ABSTRACT. Student engagement requires more than visible participation: children must feel able to contribute, allocate attention to relevant information, and invest effort in understanding. This article reconstructs a neuroscience-informed learning model for elementary education through a critical integrative review of 33 journal articles published between 2017 and 2024. The synthesis combines developmental neuroscience, cognitive and educational psychology, and contextually relevant educational research. It distinguishes explanatory mechanisms from instructional evidence and avoids inferring classroom effectiveness directly from brain-based terminology. Five interconnected components are proposed: emotional readiness, attention and prior-knowledge activation, guided exploration, retrieval and reflection, and structured social interaction. Social support operates throughout the model rather than only at its final stage. The discussion specifies classroom activities, observable indicators, developmental constraints, and conditions under which each component may fail. The principal contribution is a testable design framework connecting instructional decisions with behavioral, emotional, and cognitive engagement. The model has not been evaluated as an integrated intervention; its effectiveness, feasibility, and equity implications require classroom trials with appropriate comparison conditions and delayed assessment.

Keywords: *Educational Neuroscience; Student Engagement; Elementary Education; Cognitive Load; Retrieval Practice; Integrative Review.*

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INTRODUCTION

Elementary classrooms face a practical design problem: an activity can attract attention without producing understanding, and a student can comply with instructions while remaining emotionally disconnected. Engagement therefore needs to be interpreted in relation to what children are thinking, feeling, and doing in a particular learning environment. A developmental and sociocultural account helps explain why the same task can engage one child and discourage another, depending on prior experience, relationships, and opportunities for meaningful participation (Wang et al., 2019). Neuroscience offers a complementary account of learning as a developmental process embedded in social and emotional experience. It does not, by itself, specify a lesson plan. Research on integrated development supports treating emotional experience, cognition, and relationships as interdependent, while educational neuroscience emphasizes the translational steps needed between neural explanations and educational decisions. Instructional recommendations must consequently be tested at the level at which they are intended to operate: classroom learning (Immordino-Yang et al., 2019; Thomas et al., 2019).

The science of learning and development provides a broader basis for this translation,

including supportive relationships, meaningful learning opportunities, and attention to individual developmental pathways. Within this perspective, teachers need to coordinate content instruction with conditions that make participation possible. A neuroscience-informed model is useful only if it clarifies these decisions and makes its assumptions open to evaluation (Darling-Hammond et al., 2020). Motivation adds another necessary distinction. Interest and willingness to participate are influenced by whether learners experience competence, autonomy, and relatedness; simply adding rewards or entertaining materials does not establish these conditions. Evidence on pathways to student motivation links teacher autonomy support and psychological need satisfaction to self-determined motivation. This suggests that engagement should be supported through accessible challenge, understandable purposes, and bounded opportunities for choice (Bureau et al., 2022; Ryan & Deci, 2020).

The challenge is particularly relevant to elementary education because instructional independence cannot be assumed. Reviews of generative learning indicate that strategies effective with university students do not necessarily work equally well with younger children. Similarly, evidence on problem solving before instruction identifies different patterns for younger learners. A model intended for elementary schools must therefore specify when guidance is required, rather than equating student-centered learning with minimal teacher support (Brod, 2021; Sinha & Kapur, 2021). The contribution of this article is a reconstruction of five established instructional components into an explicit design framework. The framework links each component to a plausible psychological mechanism, an intended engagement outcome, and a classroom indicator. It addresses three questions: Which principles can responsibly inform elementary instruction? How can they be combined into a workable sequence? What evidence would be needed to determine whether the combined model improves engagement and learning? The proposed contribution is conceptual integration and testability, not the discovery of a new neural mechanism or a claim that these pedagogical components are unprecedented.

METHOD

Review design and scope

This study uses a critical integrative literature review to develop a conceptual model. The unit of analysis is the published article, not the individual student. The final reference set contains 33 unique journal articles with publication years from 2017 through 2024. Twenty-eight articles constitute the international research set, and five articles from a SINTA 1 journal supply contextual evidence relevant to educational practice in Indonesia. This fixed composition is an editorial selection criterion; it does not establish that the corpus exhausts the relevant literature. The review draws on article records identified through targeted scholarly web searches, publisher pages, DOI metadata, and research repositories. Search concepts included educational neuroscience, elementary student engagement, emotional development, cognitive load, generative learning, retrieval practice, feedback, self-regulated learning, and cooperative learning. Bibliographic details were checked against DOI registration or publisher records. The publication year follows the final journal issue where available, so online-first dates are not automatically substituted for issue dates.

Eligibility and evidence appraisal

Eligible sources were journal articles published within the stated period and relevant to at least one model component or to its implementation conditions. Reviews, meta-analyses, conceptual articles, and empirical classroom studies were retained for different analytical purposes. Books, unverified references, publications outside the date range, and duplicate versions were excluded from the replacement bibliography. Broader-age studies were retained where they informed a mechanism or design boundary, but were not treated as direct evidence for elementary classrooms.

The synthesis distinguishes accessible abstract-level evidence from findings supported by accessible article text. It does not claim a preregistered systematic search, independent double screening, a comprehensive full-text review of all 33 articles, or a pooled effect estimate. No screening-flow totals are reported because an auditable database export and exclusion log are not available. These restrictions determine the strength of the conclusions: the review can motivate a model and identify conditions for testing, but cannot establish comparative intervention effectiveness. Evidence was considered in relation to study design, age group, outcome, and proximity to the proposed application. A theoretical account supports conceptual coherence; it does not estimate an intervention effect. A meta-analysis provides evidence across studies, but its pooled result may not describe a particular grade or national setting. Qualitative accounts inform feasibility and participant experience, whereas correlations and uncontrolled pretest–posttest changes cannot isolate causal effects. Journal rank was used for reference eligibility, not as a substitute for this appraisal.

Synthesis and model construction

The analytical structure separates four elements: the learning process described in the literature, the teaching action proposed from it, the expected engagement response, and an indicator that could challenge that expectation. Findings were organized around emotional readiness, attention, guided knowledge construction, retrieval and regulation, and social interaction. Evidence that qualified a recommendation, including age-related constraints and limits on transfer, was retained rather than excluded for contradicting a preferred model. The reconstruction produces a flexible instructional sequence with feedback loops. Each component is expressed as a teacher decision rather than a presumed brain state. For example, reducing irrelevant task demands is an instructional action; improved allocation of attention is a hypothesis; a child's explanation or task performance supplies evidence. Classroom behavior alone cannot demonstrate a particular neural change. The model consequently remains a set of testable propositions connecting instruction with engagement and learning.

RESULT AND DISCUSSION

Result

Results of the conceptual synthesis

The literature supports a distinction between evidence for individual instructional practices and evidence for the proposed package. The selected articles offer convergent reasons to coordinate emotional support, manageable task demands, meaningful processing, retrieval, and interaction. They do not directly test the five-component model as a complete intervention. Table 1 organizes the evidence by its role in model construction; the complete bibliography contains all 33 sources.

Table 1 Evidence informing model reconstruction

Evidence domain	Selected evidence	Interpretive boundary
Development and emotion	Neuroscience and developmental syntheses (Immordino-Yang et al., 2019; Thomas et al., 2019)	Explanatory foundation; no direct test of the proposed package.
Attention and task design	Cognitive load and multimedia reviews (Mayer, 2017; Sweller et al., 2019)	Design principles depend on content and prior knowledge.

Evidence domain	Selected evidence	Interpretive boundary
Guided construction	Age-sensitive and instructional sequencing reviews (Brod, 2021; Sinha & Kapur, 2021)	Adult findings cannot be applied uniformly to younger pupils.
Retrieval and regulation	Classroom retrieval and self-regulation syntheses (Agarwal et al., 2021; Dignath & Veenman, 2021)	Learning and engagement require distinct measures.
Interaction	Peer-interaction synthesis and Indonesian teacher case study (Karmina et al., 2024; Tenenbaum et al., 2020)	Group work needs explicit structure; qualitative evidence is contextual.
Implementation	Indonesian competency and professional-growth studies (Musa et al., 2024; Salamah, 2024)	Correlations and case accounts do not establish intervention effects.

The reconstructed sequence begins with readiness and orientation, proceeds to guided exploration, and includes retrieval, explanation, and reflection before closure. Structured interaction can occur during every phase. A later discussion may reveal a misconception and require renewed explanation; a retrieval task may expose insufficient preparation and lead to another worked example. Thus, the sequence is recursive and responsive, not a fixed biological timetable. Table 2 states the proposed actions and indicators.

Table 2. Proposed instructional components and engagement indicators

Component	Proposed teacher action	Indicator to examine
Emotional readiness	Offer predictable routines and accessible ways to answer; respond respectfully to errors.	Emotional: reported safety and interest; willingness to attempt.
Attention and prior knowledge	Identify the learning goal; elicit a relevant prior idea; remove competing information.	Behavioral: task-relevant responses, supported by a short content check.
Guided exploration	Model prerequisites; invite predictions, comparisons, and explanations; adjust guidance.	Cognitive: explanation quality and evidence-based revision.
Retrieval and reflection	Ask for recall without notes; give actionable feedback; revisit the idea later.	Cognitive: strategy use and revision; assess delayed learning separately.
Structured interaction	Use rotating roles and shared reasoning; check each pupil's understanding.	Behavioral and emotional: equitable contribution and belonging; cognitive: co-explanation.

Discussion

Emotional readiness and the quality of participation

Emotional readiness refers here to willingness and perceived safety to enter a learning task, not a requirement that every child feel happy before learning. The developmental literature connects social-emotional experience with learning, but does not justify a claim that a brief classroom routine directly switches the brain into an optimal state. The practical implication is to make expectations predictable, respond respectfully to errors, and provide routes into participation for children who hesitate to speak (Immordino-Yang et al., 2019). Affective teacher student relationships are associated with engagement and achievement, with engagement examined as a mediating process in a meta-analytic synthesis. This strengthens the rationale for relational support while leaving room for reciprocal influences and contextual differences. A classroom application proposed here is a predictable opening routine in which children can respond orally, point to an option, or write a short answer. These alternatives should be evaluated for whether they expand participation, rather than assumed to work because they appear reassuring (Roorda et al., 2017).

Meta-analyses of school-based social and emotional learning report benefits across several developmental and educational outcomes, including follow-up outcomes, while also showing that program content and implementation context matter. These findings support a sustained classroom approach; they do not establish that an isolated icebreaker reproduces the effects of a structured SEL program. Emotional support should therefore continue during difficult tasks, feedback, and peer disagreement (Cipriano et al., 2023; Taylor et al., 2017). For implementation, a teacher might acknowledge frustration during a fraction task, restate an achievable next step, and invite a private response before a public explanation. Success would be indicated by renewed participation and a clearer account of the concept, not smiling alone. Conversely, persistent avoidance, embarrassment, or exclusion would challenge the assumption that the learning environment is supportive. A child-friendly learning-management study in elementary physical education supplies relevant design considerations concerning inclusion and rights, although its feasibility assessments do not demonstrate engagement gains from the present model (Sunardianta et al., 2024).

Attention and prior knowledge as design constraints

Attention stimulation should direct children toward conceptually relevant features. Novelty that competes with the learning goal can consume the very resources it is intended to mobilize. Cognitive load theory identifies the importance of the relationship between limited processing capacity, prior knowledge, and instructional demands. For unfamiliar material, the model therefore proposes short explanations, clear examples, and explicit identification of the features children should compare (Sweller et al., 2019). Multimedia principles strengthen this recommendation by distinguishing useful combinations of words and graphics from unnecessary processing. A representation should help explain an idea: a labeled diagram of evaporation, for example, should coordinate with the teacher's explanation. Decorative animation, simultaneous unrelated sound, and densely written slides may undermine that purpose. The relevant decision is how information supports understanding, not how many sensory channels are stimulated (Mayer, 2017).

Prior-knowledge activation also serves a diagnostic function. Before teaching equivalent fractions, the teacher can ask children to represent one-half and explain whether differently shaped parts are equal. Their answers reveal misconceptions that a general question such as "Do you remember fractions?" can conceal. The next step can then vary: some pupils may need concrete comparison, whereas others can examine symbolic equivalence. This is a proposed application of the framework, not an empirically validated lesson sequence. Attention should be assessed through task-relevant responses, not inferred exclusively from eye contact or stillness. A

child looking away may be thinking, and a child looking at the board may not understand. Short questions, annotations, or explanations offer more informative evidence of what has been selected and processed. The model therefore pairs observation with an accessible content task and avoids using visible compliance as the sole behavioral-engagement measure.

Guided exploration and constructive cognitive engagement

Exploration becomes educationally productive when learners generate or revise an explanation, prediction, or solution. The ICAP translation study distinguishes engagement modes and documents the difficulty teachers experienced in designing constructive and interactive activities. Its findings caution against labeling all hands-on tasks as cognitively demanding: manipulating materials can remain superficial if learners are not asked to explain the relevant relation (Chi et al., 2018). Generative learning research further suggests that explaining, visualizing, and enacting can serve complementary sense-making functions. In the proposed model, an experiment is followed by a prompt that connects the observed event to a concept. For instance, children might compare two melting conditions, predict which will change faster, and explain the result using the target vocabulary. The purpose of the activity is the relation children construct, rather than the amount of movement or equipment involved (Fiorella, 2023).

Developmental constraints are decisive. Brod's review reports mixed evidence for younger learners across generative strategies, with some approaches supported earlier than others. Teachers should not assume that asking children to generate questions or drawings automatically improves learning. Prompts, partial examples, and guided comparison may be necessary; the children's products should be inspected for conceptual accuracy rather than rewarded solely for completion (Brod, 2021). The productive-failure meta-analysis also prevents an overly simple recommendation to let students struggle before every explanation. Although the synthesis favors problem solving before instruction overall, its younger-learner pattern favors instruction before problem solving. For elementary classes, the model consequently proposes adaptive sequencing: explicit preparation for unfamiliar prerequisites, a manageable exploration task, and a teacher-led consolidation that corrects errors. The appropriate amount of initial guidance remains an empirical question for each content and grade (Sinha & Kapur, 2021). Indonesian evidence offers a concrete but limited illustration. A study of Canva-assisted Modelling the Way in a fourth-grade Islamic education class reported improved posttest scores among 31 pupils. Because it used a single-group pretest–posttest design, the change cannot be uniquely attributed to the strategy, Canva, or a neuroscience mechanism. It supports further investigation of modeled practice in context, while illustrating why a comparison group and distinct engagement measures are necessary (Sunarso & Herdianto, 2024).

Retrieval reflection and feedback for durable learning

Memory strengthening should involve opportunities to retrieve and use what was learned rather than only rereading it. A systematic review of applied classroom research identified benefits of retrieval practice across several conditions but noted limited representation of non-WEIRD contexts. This offers a substantial rationale for classroom retrieval while preserving the need for local validation. In the model, retrieval is brief, low stakes, and followed by an opportunity to resolve errors (Agarwal et al., 2021). Meta-analyses of practice testing and classroom quizzing provide additional support for learning benefits while identifying variation across task and study conditions. These findings concern learning outcomes; they should not be automatically redescribed as evidence that testing increases emotional engagement. Teachers should monitor whether questions are accessible and whether pupils experience retrieval as an opportunity to learn rather than a public ranking exercise (Adesope et al., 2017; Yang et al., 2021).

Transfer requires separate attention. A meta-analysis of test-enhanced learning indicates that transfer is conditional, so reproducing a practiced answer does not by itself show flexible

understanding. A proposed progression is to retrieve an explanation, apply it to a similar example, and then explain a changed case. The resulting tasks should distinguish recall from transfer rather than combine both into an undifferentiated achievement score (Pan & Rickard, 2018).

Feedback completes the cycle only when pupils can use it. The educational feedback meta-analysis emphasizes variation in effectiveness across forms of feedback; a single average should not be interpreted as proof that any comment helps. A practical response is to identify the relevant error, explain the criterion, and provide time for revision. "These parts are unequal; compare their sizes before naming the fraction" supplies a next action, whereas a score alone may leave the learner uncertain about how to proceed (Wisniewski et al., 2020). Reflection also requires instruction. A review of classroom observation studies found limited direct teaching of self-regulation strategies, and a separate meta-analysis examined sustained effects of metacognitive strategy instruction. The model therefore includes teacher modeling of how to plan, check, and revise, followed by guided student use. Asking "What did you learn?" is insufficient when children have not learned how to evaluate understanding or identify a useful next step (de Boer et al., 2018; Dignath & Veenman, 2021). A feasible closing routine might combine one retrieval question, one explanation of an error, and one plan for another attempt. A later lesson can revisit the same concept with a changed example. These are proposed routines, not prescribed durations or a validated spacing schedule. Teachers should record whether pupils improve after feedback and whether knowledge remains available later; immediate ease and confidence are not enough to establish durable learning.

Social interaction and autonomy across the model

Social interaction is treated as an organizing condition across the lesson. The peer-interaction meta-analysis includes children aged 4 to 18 and reports learning benefits across comparisons, providing stronger age-relevant support than an extrapolation from adult collaboration alone. Nevertheless, a group arrangement is not equivalent to productive interaction. Children need a shared problem, opportunities to explain, and a reason to attend to one another's contributions (Tenenbaum et al., 2020). The proposed classroom design assigns temporary roles such as explaining, questioning, and checking, then rotates them so that participation is not concentrated in a confident pupil. An individual response after discussion helps reveal whether each child can use the idea. Peer assessment can also contribute when criteria are understandable: its meta-analysis reports a modest positive average effect on performance, but does not remove the need for teacher oversight or age-appropriate preparation (Double et al., 2020).

The Indonesian case study by Karmina and colleagues contributes locally relevant implementation evidence from seven elementary teachers. Its themes include group roles, meaningful interaction, and consensus decision-making. These accounts support attention to how cooperation is organized, but they cannot estimate the causal effect of the reconstructed model. In the present design, the teacher checks whose ideas enter the group product and whether disagreement concerns evidence rather than personal criticism (Karmina et al., 2024). Autonomy support must accompany this structure. A review of autonomy-supportive teaching describes its potential for improving educational practice, while self-determination research distinguishes voluntary engagement from externally controlled participation. The model proposes bounded choices for example, which of two examples to explain within a clear learning goal. Choice should be substantive enough to matter without making the task so open that children lack a starting point (Reeve & Cheon, 2021; Ryan & Deci, 2020). Evidence from physical education additionally links self-determination constructs to educational outcomes in that domain. It provides a relevant motivation perspective for lessons involving movement, but should not be generalized into a claim that physical activity automatically improves learning in every subject. In this model, movement is included when it supports the content, participation, or an appropriate

transition, and its value is judged against those purposes (Vasconcellos et al., 2020).

Implementation conditions in Indonesian elementary schools

Implementation depends on teachers' pedagogical knowledge, interpretation of student responses, and opportunities to refine practice. A study of 40 first-grade teachers in Yogyakarta reported associations between teaching competencies and professional attitudes, experience, and self-concept. These correlations cannot establish which training component causes improvement, but they reinforce the need to consider teacher characteristics when evaluating adoption (Salamah, 2024). A qualitative study of ten Indonesian educators describes professional growth through feedback, collaboration, and adaptation. Its contribution is contextual insight into development processes, not a universal effect estimate. A practical implication proposed here is to introduce the model through a small lesson-design cycle: select one concept, plan indicators of participation and understanding, teach, examine student work, and revise the next lesson. Professional discussion can then focus on evidence from learning rather than the appeal of neuroscience terminology (Musa et al., 2024).

Resource demands should remain proportionate. Paper response cards, classroom objects, paired explanation, and teacher modeling can instantiate the components without requiring proprietary software or brain-monitoring equipment. Where digital media are available, the teacher should justify their role in the concept being taught and provide an alternative for pupils with limited access. Schools should also check language demands, sensory accessibility, group participation, and the time required for preparation and feedback. The framework must accommodate children who need different forms of expression or additional processing time. A silent written response, an oral explanation, and a concrete representation may provide different windows into understanding. They should not be treated as interchangeable measures without validation. Adaptations should preserve the learning goal while reducing irrelevant barriers; conclusions about engagement should draw on more than a teacher's impression of who appears enthusiastic.

Theoretical contribution and limits of neuroscience claims

The model's theoretical contribution is a chain of explicit propositions. Supportive participation conditions are expected to increase willingness to attempt a task; manageable demands and suitable guidance are expected to improve relevant processing; retrieval, feedback, and interaction are expected to support revision and later access to knowledge. Each proposition can fail, and the integrated package could impose coordination costs that offset its benefits. This makes the model open to disconfirmation rather than insulated by a general claim that it is "brain compatible." Educational neuroscience calls for care when translating basic science into policy or practice. Likewise, reviews of far transfer from chess, music, and working-memory training cast doubt on broad cognitive-enhancement claims. The present model does not assume that a generic brain exercise produces wide academic improvements. Instruction remains tied to subject content and to outcomes that can be observed and assessed (Sala & Gobet, 2017; Thomas et al., 2019).

Claims about motivational messages also need restraint. The growth-mindset meta-analyses report weak overall effects and relevant boundary conditions, so encouraging language alone should not be presented as a reliable route to large achievement gains. Within the model, encouragement is paired with a feasible strategy, appropriate guidance, and another opportunity to act. The intended mechanism is support for participation in a specific task, not a promise of generalized cognitive transformation (Sisk et al., 2018).

Evaluation priorities and limitations

The next research step is a feasibility study followed by a controlled classroom evaluation. The proposed comparison should match instructional content, time, assessment opportunities,

and teacher support as closely as possible. Where feasible, allocation at class or school level would reduce contamination; analyses should account for clustering and baseline differences. These are recommendations for future research, not procedures completed in this review. Behavioral engagement could be assessed through sampled task participation and contribution opportunities. Emotional engagement requires developmentally appropriate student reports of interest, safety, and belonging. Cognitive engagement could be investigated through explanation quality, strategy use, and revision after feedback. These outcomes should be kept distinct from immediate achievement and delayed retention. The assessment plan should specify its primary outcome in advance and examine measurement reliability and accessibility.

Implementation fidelity should document which components were delivered, the guidance provided, and whether all pupils had opportunities to respond. Teacher workload, preparation time, adverse experiences, and participation inequalities should also be recorded. If the package improves one outcome while increasing anxiety or excluding some pupils, a single mean engagement score could conceal an important tradeoff. Process evidence would help determine whether a weak result reflects the design, its implementation, or the assumptions behind it. The present synthesis has substantive limitations. Its targeted selection and fixed reference composition may privilege particular perspectives; multiple reviews may also share underlying studies and must not be counted as independent replications. Access to complete article text was uneven, and no formal risk-of-bias assessment or new meta-analysis was conducted. The five Indonesian sources all come from one journal, restricting contextual breadth. International studies span different ages and settings, while most selected evidence concerns components rather than their combination. Accordingly, the model is a reasoned proposal for testing, not an established effective intervention.

CONCLUSION

A neuroscience-informed elementary learning model can be made more defensible by connecting developmental explanations to established instructional evidence and observable engagement indicators. The proposed reconstruction coordinates emotional readiness, attention and prior knowledge, guided exploration, retrieval and reflection, and structured social interaction. Its central design requirement is adaptation: guidance must fit prior knowledge and age, social participation must be equitable, and feedback must lead to another learning action. The synthesis does not demonstrate that the integrated model improves engagement or achievement. It provides a framework for teachers and researchers to specify actions, examine children's responses, and test competing explanations. Future studies should evaluate feasibility, compare the model with a credible instructional alternative, and measure engagement alongside delayed learning and implementation demands. Claims about neural change should be reserved for studies designed to measure it.

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