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The Lapbook As A Tool For Enhancing Students' Cognitive Activity In Science Education

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Abstract: Active, generative engagement is a decisive predictor of learning gains in science education, yet many university methods courses still rely on transmissive routines that leave pre-service teachers as passive recipients of information. This paper investigates the lapbook—a student-constructed, interactive folder composed of flaps, pockets, and mini-books—as a low-cost, high-structure medium for orchestrating cognitive activity in natural science lessons. Drawing on constructivism, multimedia learning, cognitive load theory, and generative learning, we propose a mechanism by which lapbooks coordinate dual coding, elaboration, self-explanation, retrieval practice, and metacognitive monitoring. We then report a quasi-experimental study with 120 second-year pedagogical university students enrolled in a science methods course. An eight-week intervention contrasted lapbook-centered lessons with business-as-usual workbook activities. Outcomes included a Cognitive Activity in Science Scale (CASS), a performance-based project rubric, a delayed retention test, and systematic classroom observations. Compared with controls, the lapbook group demonstrated significantly greater post-intervention cognitive activity (CASS $M = 3.82$ vs. 3.33 on a 5-point scale; $t(118) = 6.40$, $p < .001$, $d = 1.17$), higher transfer and self-regulation subscale scores, improved project quality, and stronger four-week retention (78.4% vs. 69.1%). Observational evidence indicated sustained time-on-task and more frequent student-initiated explanations. We interpret these effects as the result of structured generative production coupled with externalized knowledge organization that lightens extraneous load while enriching semantic networks. The paper concludes with design principles for integrating lapbooks into methods courses and school placements, limitations concerning instructor fidelity and measurement generalizability, and

implications for pre-service teacher preparation in inquiry-oriented science.

Keywords: Lapbook; cognitive activity; generative learning; dual coding; science education; pre-service teachers; multimedia learning; metacognition.

Introduction: Science education has long sought practicable ways to mobilize learners' cognitive resources beyond mere exposure to content. A robust body of research shows that when students generate, organize, and explain ideas, they build richer schemas, regulate their effort more efficiently, and remember more over time (Hattie, 2009; Fiorella, Mayer, 2015). Pre-service teachers, however, often encounter natural science methods as a sequence of demonstrations to observe and replicate, rather than as a design space in which to construct meaning. This tends to narrow their pedagogical content knowledge and weakens the very dispositions—curiosity, planning, monitoring, and self-evaluation—that they will later need to cultivate in school pupils.

The lapbook method, widely used in informal and early schooling contexts, has been under-theorized in higher education. A lapbook is a foldable, student-authored knowledge artifact: a file folder or large sheet reconfigured with flaps, pockets, mini-booklets, wheels, and tabs that together house definitions, diagrams, micro-reports, data tables, and questions. In contrast to linear note-taking, a lapbook's spatial topology affords grouping, layering, and cross-referencing. The medium's affordances can be mapped to well-studied mechanisms. First, dual coding and multimedia learning are engaged as learners pair hand-drawn or printed visuals with concise verbal labels, captions, and explanations (Paivio, 1986; Mayer, 2009). Second, generative strategies—summarizing, self-explaining, and analogizing—are built into the act of deciding what to include and how to represent it (Fiorella, Mayer, 2015). Third, a lapbook turns invisible metacognition outward: because the artifact is assembled over multiple lessons, learners must plan, monitor progress, and evaluate completeness, thereby practicing self-regulation.

From a cognitive load perspective, lapbooks may reduce extraneous load by providing stable places to attach and revisit information while increasing germane load through productive re-organization (Sweller, Ayres, Kalyuga, 2011). The artifact thereby becomes a tangible scaffold for the "learning by design" stance that underlies project-based and inquiry-rich science (Krajcik, Blumenfeld, 2014). As pre-service teachers design lapbooks in their own

methods courses, they acquire a repertoire for later facilitating similar generative activity among school students, including opportunities for retrieval practice and spaced consolidation, both of which are reliably associated with improved retention.

Despite these theoretical connections, higher-education literature features few empirical examinations of lapbooks with adult learners or future teachers. The practice is sometimes dismissed as craft-heavy, yet such criticism conflates low-level decoration with purposeful external representation. A critical question is whether lapbooks can be implemented with sufficient academic rigor to increase cognitive activity without devolving into time-consuming scrapbooking. To address this, we articulated design constraints that foreground conceptual structure, explanatory writing, and representational alignment—not aesthetic embellishment.

The present study, embedded in a science methods course at a pedagogical university, assessed whether integrating lapbooks would measurably enhance students' cognitive activity compared with conventional workbook-centered instruction. We anticipated that lapbooks would increase elaboration, transfer, and self-regulation, improve project performance, and support delayed retention, while classroom observations would reveal greater time-on-task and more frequent student-initiated explanations. By pairing theory with systematic measurement, the study aims to clarify the lapbook's value for cultivating the cognitive habits that pre-service teachers must carry into their future classrooms.

The study aimed to determine the effectiveness of the lapbook method as a catalyst of cognitive activity in a university science methods course for pre-service teachers. Specifically, we sought to test whether an eight-week lapbook intervention would increase students' self-reported cognitive activity and its components—elaboration, transfer, and self-regulation—relative to business-as-usual instruction; to examine whether any gains translated into higher performance on a structured, content-aligned project rubric and into stronger retention on a delayed test; and to characterize changes in classroom participation patterns indicative of active, generative engagement. A secondary aim was to connect observed outcomes to a theoretically grounded account of how lapbooks mediate learning through dual coding, generativity, and regulated effort.

The research used a quasi-experimental, pretest–posttest control group design in a pedagogical university's compulsory natural science methods course. Participants were 120 second-year pre-service teachers (86 female, 34 male; mean age 19.7 years)

enrolled in four intact sections taught by two instructors trained to comparable levels of fidelity. Sections were randomly assigned at the class level: two sections ($n = 60$) constituted the lapbook condition and two ($n = 60$) served as controls. No participant had prior experience with lapbooks at university level, and baseline measures indicated similar prior science achievement and reading proficiency across groups.

The intervention spanned eight weeks and addressed topics selected from the course syllabus—ecosystem dynamics, energy and simple machines, weather systems, human physiology, and properties of matter. In the lapbook condition, each topic contributed a dedicated mini-book or interactive element integrated into a cumulative folder. Sessions began with a brief focal phenomenon, after which students derived guiding questions, consulted brief texts and diagrams, and produced representational elements that paired a concise explanation with a diagram, table, or model. Templates were deliberately minimal to avoid decorative overload and to prompt design decisions about structure and explanatory prose. Instructors modeled how to compress explanations, align visuals with text, and cite sources. The control sections covered identical content using lectures, textbook passages, and workbook exercises, followed by short quizzes; students kept linear notes but did not produce lapbooks or other design artifacts.

Outcome measures included the Cognitive Activity in Science Scale (CASS), a 24-item Likert instrument adapted from existing engagement frameworks and piloted in prior cohorts. The CASS comprised three subscales—elaboration (e.g., connecting new ideas to prior knowledge), transfer (e.g., applying concepts to novel contexts), and self-regulation (e.g., planning and monitoring)—with Cronbach's alpha values of .86, .81, and .83 respectively and .90 for the total scale. A performance rubric evaluated the conceptual accuracy, explanatory depth, representational alignment, and coherence of students' culminating portfolios; two raters, blind to condition, scored each portfolio, achieving an intraclass correlation of .89. A delayed retention test four weeks after the intervention assessed recall and application through short-answer items and a brief data interpretation task aligned to the covered topics. Classroom observations used a time-sampling protocol to record time-on-task and instances of student-initiated explanations during paired or group work; 20% of sessions were double-coded, yielding a Cohen's kappa of .82.

Data analysis proceeded in several stages. Independent-samples t tests compared groups at pretest to verify baseline equivalence. Primary effects were examined with ANCOVA on posttest outcomes

using pretest scores as covariates. Cohen's d supplemented significance tests to express effect sizes. Exploratory analyses tested whether outcomes varied by instructor or prior GPA; interaction terms were non-significant and are not elaborated. All procedures conformed to institutional ethical guidelines for research with adult learners; participation was voluntary with informed consent, and coursework grades were insulated from research measures by using external raters.

At baseline, no statistically significant differences were found between the lapbook and control groups on the CASS total score or its subscales. The lapbook group's pretest total averaged $M = 3.02$ ($SD = 0.41$) and the control group's $M = 3.05$ ($SD = 0.44$) on a five-point scale, $t(118) = 0.41$, $p = .68$, indicating functional equivalence and supporting the internal validity of subsequent contrasts.

Following the eight-week intervention, the lapbook group outperformed the control group on the CASS total score after adjusting for pretest, with an adjusted mean of 3.82 ($SE = 0.04$) versus 3.33 ($SE = 0.04$). The difference was statistically significant, $F(1,117) = 40.92$, $p < .001$, with a large effect ($d = 1.17$). Subscale analysis revealed a coherent pattern: elaboration increased most dramatically where students had to compress multiple representations into an integrated mini-book, rising from $M = 2.95$ to 3.79 in the lapbook group compared with 2.97 to 3.31 among controls, $t(118) = 5.21$, $p < .001$, $d = 0.95$. Transfer gains were substantial as well, reflecting the repeated requirement to connect a focal phenomenon to system-level principles; lapbook students moved from $M = 3.01$ to 3.86 against the control group's 3.03 to 3.37, $t(118) = 5.58$, $p < .001$, $d = 1.02$. Self-regulation improved from $M = 3.10$ to 3.80 in the lapbook cohort versus 3.14 to 3.31 in controls, $t(118) = 4.71$, $p < .001$, $d = 0.86$, consistent with the view that the artifact's cumulative structure invites planning and ongoing monitoring.

Performance-based assessments converged with the self-report data. Portfolios from the lapbook sections achieved higher ratings for conceptual accuracy and explanatory depth, and they exhibited tighter alignment between visuals and text. The most distinctive difference lay in the coherence of causal explanations in topics like energy transfer and homeostasis, where lapbook entries typically layered a system diagram under a flap with a brief narrative that articulated links, constraints, and counterexamples. Raters noted that these entries were not simply pictorial but constituted compact argumentation. This pattern aligns with research showing that generative production, particularly in mixed verbal-visual formats, strengthens the organization of knowledge and its accessibility

during problem solving (Mayer, 2009; Fiorella, Mayer, 2015).

The delayed retention test administered four weeks later further supported the intervention's efficacy. The lapbook group scored 78.4% (SD = 9.7) overall compared with 69.1% (SD = 10.2) in the control group, $t(118) = 5.00$, $p < .001$, $d = 0.92$. Item analysis indicated that the largest advantages occurred on application items requiring students to interpret unfamiliar data in light of underlying principles, suggesting that the representational synthesis embedded in lapbook construction facilitated durable, transferable schemas rather than short-lived memorization.

Classroom observations documented qualitative changes in participation. Time-on-task rose by approximately thirteen percentage points in the lapbook sections relative to controls, and student-initiated explanations during small-group work were more frequent and sustained. Rather than merely completing workbook items, students negotiated how to partition a concept into parts, which visual to use, and how to phrase an explanation concisely enough to fit into a flap while preserving causal clarity. These negotiations are not peripheral: they are the activity of learning itself. In Vygotskian terms, the lapbook functioned as a shared mediational artifact that structured the zone of proximal development by coordinating joint attention and making thinking public for scaffolding (Vygotsky, 1978). The artifact's persistence across sessions also underwrote spaced retrieval as students reopened and reorganized sections, a practice known to improve long-term retention.

Theoretically, the lapbook's efficacy can be understood as the conjunction of four mechanisms. First, dual coding enhances memory by binding visual and verbal traces (Paivio, 1986), which lapbooks operationalize by requiring each diagram, table, or wheel to carry an adjacent explanation. Second, generative learning is catalyzed when learners must decide what to include and how to represent it, because such decisions trigger elaboration, self-explanation, and selection processes that reorganize knowledge (Fiorella, Mayer, 2015). Third, cognitive load is managed as the stable topology of the folder reduces extraneous search and supports chunking, while the effort invested in organizing material increases germane load directed at schema construction (Sweller, Ayres, Kalyuga, 2011). Fourth, metacognitive regulation is exercised in the iterative assembly of the artifact, which calls for planning, monitoring, and evaluation of completeness and coherence; these activities were reflected in the self-regulation subscale gains.

Concerns that lapbooks might devolve into decorative scrapbooking were mitigated by design constraints that required alignment between visuals and explanatory text and by assessment criteria that privileged conceptual clarity. Instructor fidelity mattered: modeling how to compress and phrase explanations, and enforcing a norm of citing sources even in concise captions, helped maintain academic rigor. Importantly, the intervention was resource-light. Materials were inexpensive, and the core value lay in the representational decisions learners made rather than in elaborate materials. In this way, the method is scalable in contexts where laboratory resources are limited yet inquiry and sense-making remain curricular imperatives.

Limitations include the quasi-experimental design with intact classes, which raises the possibility of unmeasured group differences. Although instructor effects were checked and found non-significant, future randomized trials across multiple institutions would strengthen causal inference. The CASS, while reliable, is a self-report instrument; triangulation with process data such as trace logs from digital lapbooks or think-aloud protocols would refine measurement of cognitive activity. The scope of content topics was broad but not exhaustive; alternative scientific domains could reveal boundary conditions, particularly where representational demands differ. Finally, we did not test long-term impacts on pre-service teachers' practice during school placements, an essential step for linking university-level cognitive activity to classroom enactment.

Despite these constraints, the present findings advance a concrete, theoretically anchored, and logistically accessible approach for cultivating the cognitive dispositions central to science learning. The lapbook method transformed the methods classroom from a site of reception into a studio of sense-making, with measurable gains in elaboration, transfer, and regulation and with artifacts that made understanding visible. For teacher educators committed to inquiry-rich pedagogy, lapbooks offer a bridge between theory and practice by embedding generative learning into the fabric of everyday lessons.

The study demonstrates that integrating lapbooks into a university science methods course substantially enhances students' cognitive activity and learning outcomes. By compelling learners to design, align, and justify representations, the lapbook becomes a mediational artifact through which dual coding, generative processing, and metacognitive control operate in concert. The resulting gains are not limited to improved self-reports: they manifest in higher-quality explanatory products, increased classroom initiative,

and stronger delayed retention. For teacher education, the implications are twofold. First, methods courses can adopt lapbooks as a routine structure for inquiry lessons without heavy resource demands while preserving academic rigor through clear assessment criteria. Second, pre-service teachers who experience learning as design acquire a portable practice they can adapt for pupils, thereby amplifying the culture of active, generative engagement in school science. Future work should extend the design to digital lapbooks that capture process data, examine domain-specific adaptations, and track transfer into student-teaching contexts. In a field seeking practical means to make thinking both visible and durable, lapbooks offer a compelling, evidence-aligned tool.

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