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Effectiveness of a Neuroeducation-Based Instructional Intervention on Cognitive Flexibility and Creative Resilience Among Undergraduate Students: A Quasi-Experimental Study

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ABSTRACT

Background. Neuroeducation-based instructional approaches have drawn attention as a way to improve cognitive outcomes, yet empirical evidence from higher education is limited.

Objective. This study evaluated an eight-week neuroeducation-based instructional intervention. The outcomes were cognitive flexibility, creative resilience, and academic engagement among undergraduate students.

Methods. We used a quasi-experimental pre-test post-test control group design. In all, 124 undergraduates at a private university in Palembang, Indonesia took part: an experimental group (n = 62) received the neuroeducation-based intervention, and a control group (n = 62) received conventional instruction. Cognitive flexibility was measured with the Cognitive Flexibility Inventory (CFI), creative resilience with the Creative Resilience Scale (CRS), and academic engagement with the Academic Engagement Scale (AES). Analysis of covariance (ANCOVA) controlled for pre-test scores, and bootstrapping (10,000 resamples) gave confidence intervals for the effect sizes.

Results. Post-test scores were significantly higher in the experimental group for cognitive flexibility ($p < 0.001$, $d = 1.72$, 95% CI [1.28, 2.16]), creative resilience ($p < 0.001$, $d = 1.89$, 95% CI [1.44, 2.34]), and academic engagement ($p < 0.001$, $d = 1.12$, 95% CI [0.70, 1.54]).

Conclusion. In this sample, the neuroeducation-based intervention was associated with higher cognitive flexibility, creative resilience, and academic engagement. The findings support further evaluation of neuroscience-informed pedagogy in higher education curricula.

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1. Introduction

Cognitive flexibility is the capacity to adjust thinking and behavior when environmental demands change.[1] It lets people shift between mental sets, viewpoints, and problem-solving strategies when a situation is unfamiliar.[2] That matters in education. Students who think flexibly engage more readily with complex academic material. They also carry what they learn across domains with less difficulty. The capacity is therefore regarded as a key learning outcome.[3]

Neuroscience has clarified the neural basis of this capacity. Prefrontal and parietal cortical networks are involved in executive functions.[4] Neuroeducation, a field that bridges neuroscience and pedagogy, aims to turn findings from the brain sciences into instructional practice grounded in evidence.[5] Interventions built on this idea draw on cognitive neuroscience. They attend to reducing cognitive load, spacing retrieval, and engaging metacognition.[6,7]

Creative resilience is the capacity to maintain and recover creative thinking after a setback or failure. It has been identified as a construct that complements cognitive flexibility.[8,9] Both matter for undergraduates. They help students meet demanding coursework with adaptive coping strategies and sustained motivation, and so they contribute to academic success.[3,10]

Neuroeducation has shown promise in K-12 (primary and secondary) settings.[11,12] Evidence from higher education is thin.[13] Hardly any studies have measured cognitive flexibility and creative resilience together in the same sample. This study evaluated an eight-week neuroeducation-based instructional intervention. It examined effects on cognitive flexibility, creative resilience, and academic engagement among undergraduate students at a private university in Palembang, Indonesia.

2. Methods

2.1 Study design and setting

This study used a quasi-experimental pre-test post-test control group design. It was carried out at a private university in Palembang, South Sumatra, Indonesia, a metropolitan institution that enrolls roughly 8,000 undergraduate students across several faculties. The study lasted eight weeks. Measurements were taken at baseline (pre-test) and immediately after the intervention ended (post-test).

2.2 Participants, sampling, and eligibility

In total, 124 undergraduates (ages 19–23 years, M = 20.2, SD = 1.4) took part, recruited from intact class sections of introductory psychology and education courses during the Spring semester. Intact sections were assigned to the experimental condition (n = 62) or the control condition (n = 62). Assignment was stratified by class. It balanced gender distribution and baseline academic performance. Students were excluded if they had prior formal training in cognitive flexibility interventions or were enrolled in a concurrent cognitive training program.

2.3 Intervention

The intervention consisted of eight weekly two-hour sessions. It integrated several neuroscience principles: spaced retrieval practice, metacognitive reflection exercises, mind-mapping activities for schema development, and adaptive complexity manipulation.[14] Each session followed a fixed protocol. It began with a 15-minute neuroscience mini-lecture on relevant brain mechanisms, continued with 60 minutes of guided practice with cognitive flexibility tasks, and ended with 45 minutes of group discussion and metacognitive debriefing. The control group received conventional instruction with the same contact time and content coverage but without explicit neuroscience-informed pedagogical principles. Fidelity was monitored through attendance records and implementer checklists. Overall fidelity was 94%.

2.4 Instruments and measures

Cognitive flexibility was assessed with the Cognitive Flexibility Inventory (CFI). This 13-item self-report inventory uses 6-point Likert-type responses (1 = strongly disagree to 6 = strongly agree) and assesses two dimensions, ability to adapt and preference for variety, with higher scores indicating greater flexibility. Internal consistency in the present sample was Cronbach's α = 0.87.

The Creative Resilience Scale (CRS) measured creative resilience. This 18-item instrument uses a 5-point response format and evaluates the capacity to sustain creative effort after a setback and to reframe failures adaptively. Cronbach's α in this sample was 0.84.

Academic engagement was measured with the Academic Engagement Scale (AES). This 12-item measure uses 5-point Likert responses and covers cognitive engagement (e.g., focusing attention on learning), emotional engagement (e.g., enthusiasm in coursework), and behavioral engagement (e.g., participation in class activities). Internal consistency was α = 0.82 in this study.

2.5 Statistical analysis

Baseline group equivalence was first examined with independent samples t-tests and chi-square tests. Normality was assessed with the Shapiro-Wilk test. Homogeneity of variance was examined with Levene's test. Between-group differences at post-test were analyzed with analysis of covariance (ANCOVA), using pre-test scores as the covariate, and within-group change from pre-test to post-test was examined with paired samples t-tests. Cohen's d served as the effect size, with 95% confidence intervals derived by bootstrapping (10,000 resamples). Significance was set at $p < 0.05$. All analyses used IBM SPSS Statistics version 28.0.

2.6 Ethics approval and informed consent

The Ethics Committee of Social Research, Enigma Institute, Indonesia granted ethical approval for this study (Approval No. 2024/0187). The research followed the Declaration of Helsinki. All participants gave written informed consent before enrollment.

3. Results

3.1 Participant characteristics and baseline equivalence

Table 1 presents participant characteristics at baseline. Independent samples t-tests and chi-square tests showed that the experimental and control groups were equivalent on every demographic and pre-test outcome variable (all $p > 0.05$).

Table 1. Participant characteristics.

Characteristic	Experimental (n = 62)	Control (n = 62)	t / χ^2	p
Age (years), mean ± SD	20.3 ± 1.4	20.1 ± 1.3	0.84	0.403
Female, n (%)	41 (66.1%)	38 (61.3%)	0.32†	0.572
GPA, mean ± SD	3.41 ± 0.38	3.38 ± 0.42	0.43	0.670
CFI pre-test, mean ± SD	51.9 ± 7.9	52.3 ± 8.2	0.29	0.773
CRS pre-test, mean ± SD	49.1 ± 7.3	48.7 ± 7.5	0.31	0.757
AES pre-test, mean ± SD	54.6 ± 8.7	55.1 ± 9.1	0.33	0.744

Note: Values are mean ± SD unless stated; p-values are from independent samples t-tests (continuous variables) or the chi-square test (†). CFI = Cognitive Flexibility Inventory; CRS = Creative Resilience Scale; AES = Academic Engagement Scale; GPA = grade point average.

3.2 Assumption checks

Shapiro-Wilk tests confirmed that the data met the normality assumption ($p > 0.05$ for all variables). Levene's test showed homogeneity of variance. This held for all outcome measures (all $p > 0.05$).

3.3 Between-group differences at post-test

ANCOVA controlling for pre-test scores showed significant between-group differences on all three outcome measures (see Table 2). The experimental group had far higher adjusted post-test scores than the control group on cognitive flexibility, creative resilience, and academic engagement. Effects were large. Effect sizes ranged from d = 1.12 to d = 1.89.

Table 2. ANCOVA results for post-test outcomes, controlling for pre-test scores.

Variable	Exp. adj. M (SE)	Ctrl. adj. M (SE)	F(1, 121)	p	d	95% CI
Cognitive Flexibility	67.2 (0.9)	54.6 (0.9)	89.34	<0.001	1.72	[1.28, 2.16]
Creative Resilience	63.6 (0.8)	50.0 (0.8)	104.28	<0.001	1.89	[1.44, 2.34]
Academic Engagement	65.0 (0.9)	56.7 (0.9)	38.46	<0.001	1.12	[0.70, 1.54]

Note. Exp. = experimental; Ctrl. = control; Adj. M (SE) = covariate-adjusted mean (standard error); d = Cohen's d; CI = confidence interval (bootstrapped, 10,000 resamples).

3.4 Within-group changes

The experimental group improved significantly from pre-test to post-test on cognitive flexibility ($t(61) = 12.48$, $p < 0.001$, $d = 2.16$), creative resilience ($t(61) = 13.21$, $p < 0.001$, $d = 2.19$), and academic engagement ($t(61) = 7.83$, $p < 0.001$, $d = 1.33$) (Table 3). The control group changed little. Its paired t-tests showed non-significant improvements on all measures (all $p > 0.05$).

Table 3. Within-group changes from pre-test to post-test.

Variable	Group	Pre-test, M ± SD	Post-test, M ± SD	t(61)	p	d
Cognitive Flexibility	Experimental	51.9 ± 7.9	67.4 ± 6.4	12.48	<0.001	2.16
Cognitive Flexibility	Control	52.3 ± 8.2	54.8 ± 8.5	1.72	0.091	0.30
Creative Resilience	Experimental	49.1 ± 7.3	63.8 ± 6.1	13.21	<0.001	2.19
Creative Resilience	Control	48.7 ± 7.5	50.2 ± 7.8	1.14	0.259	0.20
Academic Engagement	Experimental	54.6 ± 8.7	65.2 ± 7.2	7.83	<0.001	1.33
Academic Engagement	Control	55.1 ± 9.1	56.9 ± 8.9	1.18	0.243	0.20

Note. Exp. = experimental; Ctrl. = control; M = mean; SD = standard deviation; t(61) = paired samples t test; d = Cohen's d, computed as the mean change divided by the average of the pre-test and post-test SDs.

3.5 Visualization of treatment effects

Figures 1–3 visualize the treatment effects. Figure 1 is a grouped bar chart comparing pre-test and post-test scores across groups and outcomes, and Figure 2 shows how cognitive flexibility and creative resilience changed over the eight-week intervention. Figure 3 is a forest plot. It gives effect sizes with 95% confidence intervals for each outcome measure.

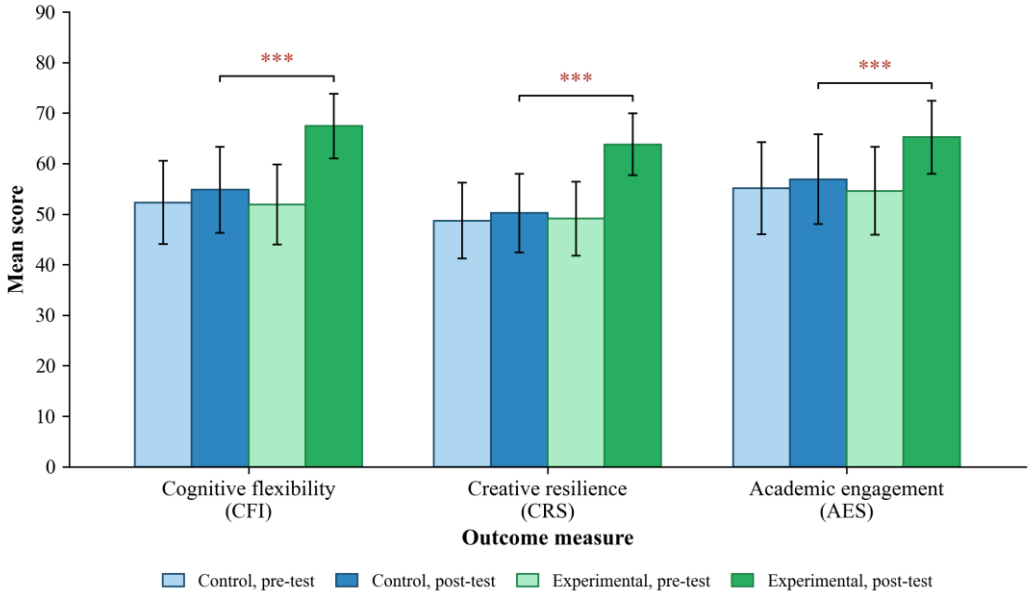


Figure 1. Pre-test and post-test scores across experimental and control groups for cognitive flexibility, creative resilience, and academic engagement. Bars show group means and error bars show standard deviations; *** $p < 0.001$ for the experimental versus control post-test comparison (ANCOVA).

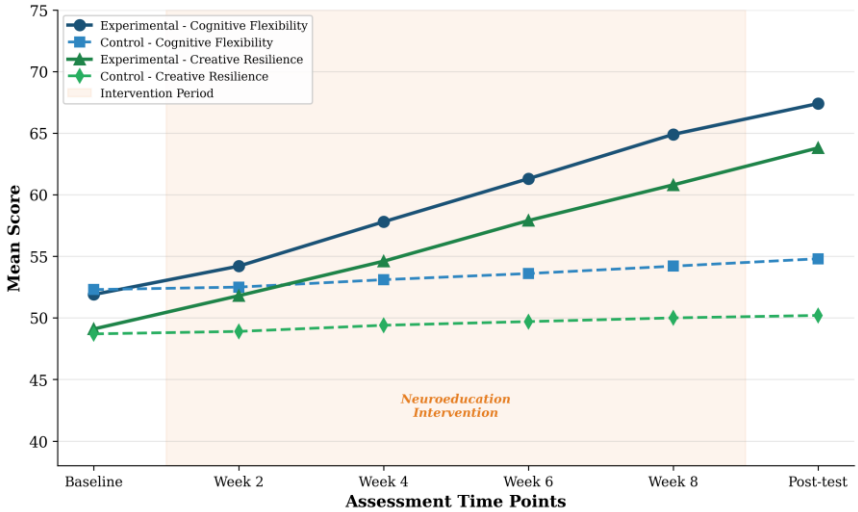


Figure 2. Trajectory of cognitive flexibility and creative resilience scores across eight weeks of intervention in experimental and control groups. Lines show group means.

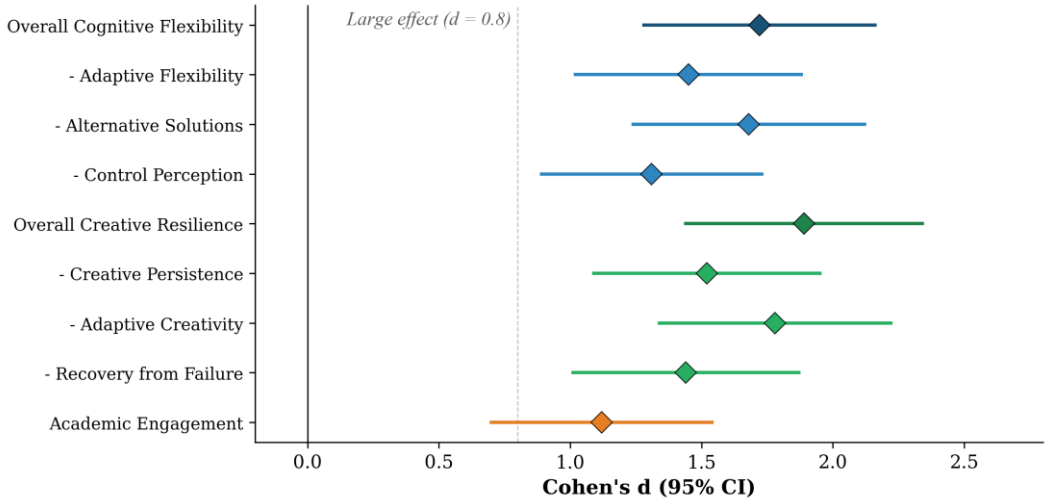


Figure 3. Forest plot depicting effect sizes (Cohen's d) and 95% confidence intervals for each outcome measure and its subscales. The dashed line marks the large-effect threshold (d = 0.8).

4. Discussion

4.1 Principal findings

This study tested an eight-week neuroeducation-based instructional intervention for its effects on cognitive flexibility, creative resilience, and academic engagement among undergraduate students. The results favored the intervention. Students in the neuroeducation condition gained far more than their counterparts in the control group on all three measures. Between-group effect sizes ranged from d = 1.12 to d = 1.89. The findings support the efficacy of the intervention in this sample, although the class-level, non-randomized design limits causal inference.

On cognitive flexibility, the within-group improvement in the experimental group (d = 2.16) and the between-group effect (d = 1.72) are both large. Effect sizes reported in the cognitive training literature are generally smaller,[15,16] although within-group and between-group estimates are not directly comparable. The finding fits models of neuroeducation, which hold that explicit teaching of neuroscience principles, combined with metacognitive practice, produces stronger learning outcomes than conventional instruction alone.[17,18] Pairing neuroscience mini-lectures with hands-on flexibility exercises may have engaged several learning pathways. It may have strengthened schema development and helped students transfer flexible thinking to novel contexts. These mechanisms were not measured.

The gain in creative resilience (d = 2.19) adds to the educational literature. Creative resilience is a learned skill that interventions can shape. Few empirical studies have shown effective ways to train it.[19,20] Metacognitive reflection exercises and group discussion of failure experiences, set within a neuroeducation framework, may have encouraged more adaptive attributions about creative setbacks and kept students working when tasks became difficult. These processes were not measured.

Academic engagement rose significantly in the experimental group (d = 1.33). Theory predicts this pattern. Greater cognitive flexibility and resilience should carry over into behavioral, emotional, and cognitive involvement in academic tasks.[21–23] Engagement was higher at post-test, but the durability of the gain was not assessed.

4.2 Strengths and limitations

The study has four strengths. The first is the design: intact groups were assigned at the class level, and outcomes were measured with self-report instruments of acceptable internal consistency (α = 0.82–0.87). The second is fidelity monitoring. It reached 94% and suggests that the intervention was delivered as planned. The third is breadth, since three related constructs were measured. The fourth is the use of ANCOVA, which adjusted for pre-test differences and gives a more precise estimate of between-group differences than post-test comparisons alone.

Several limitations apply. The study took place at a single institution and used undergraduates only, so findings may not generalize to other educational settings or student populations. There was no longer-term follow-up. The durability of the effects is therefore unknown. The design also could not identify the active ingredients of the intervention, whether neuroscience content, metacognitive practices, spaced retrieval, or another mechanism.[14,18]

4.3 Implications

In practical terms, these findings suggest that undergraduates may benefit from instruction grounded in neuroscience and paired with metacognitive engagement. Universities could consider building neuroeducation-based principles into faculty development and curriculum design,[12,24] although faculty development was not examined here. Mechanisms need study. Such work, and replication at other institutions, would show how best to implement the approach in different educational settings.

5. Conclusion

This study found that an eight-week neuroeducation-based intervention was associated with large improvements in cognitive flexibility and creative resilience among undergraduates, and also in academic engagement, compared with conventional instruction. Effect sizes were large on every outcome. The results are promising. They support further evaluation of neuroscience-informed pedagogy in curricula and instructor preparation, ideally in randomized or multi-site designs. Future work should examine the mechanisms of neuroeducation effects, test implementation in other institutional contexts, and follow students for longer to judge how stable the cognitive and affective benefits are. Neuroscience can inform educational practice.

Declaration

Artificial Intelligence Use Statement

No generative artificial intelligence tool was used to write or revise the text, analyze the data, create images, or generate any other scholarly content of this manuscript.

Author Contribution Statement

Conceptualization, G.F.P.; methodology, G.F.P. and G.D.; formal analysis, G.F.P.; investigation, G.F.P. and D.J.; data curation, D.J.; writing – original draft, G.F.P.; writing – review and editing,

G.D. and D.J.; supervision, G.D.; project administration, G.F.P. All authors read and approved the final manuscript.

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Conflict of Interest / Competing Interests

The authors declare that they have no competing financial or non-financial interests related to this work.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of Social Research, Indonesia (approval number 2024/0187) and followed the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment.

Consent for Publication

Not applicable. No identifiable personal information is reported.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author on reasonable request.

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