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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

Neuroeducation-based instructional approaches have gained attention for enhancing cognitive outcomes, yet empirical evidence in higher education remains limited. This study aimed to evaluate the effectiveness of an eight-week neuroeducation-based instructional intervention on cognitive flexibility, creative resilience, and academic engagement among undergraduate students. A quasi-experimental pre-test post-test control group design was employed. A total of 124 undergraduate students at a private university in Palembang, Indonesia were assigned to an experimental group (n = 62) receiving the neuroeducation-based intervention and a control group (n = 62) receiving conventional instruction. Cognitive flexibility was measured using the Cognitive Flexibility Inventory (CFI), creative resilience using the Creative Resilience Scale (CRS), and academic engagement using the Academic Engagement Scale (AES). Data were analyzed using analysis of covariance (ANCOVA) controlling for pre-test scores, with bootstrapped effect size confidence intervals (10,000 resamples). The experimental group showed significantly higher post-test scores compared to the control group on 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]). In conclusion, neuroeducation-based instructional interventions can substantially enhance cognitive flexibility and creative resilience among university students, supporting the integration of neuroscience-informed pedagogy into higher education curricula.

## 1. Introduction

Cognitive flexibility represents a core cognitive capacity that enables individuals to adapt their thinking and behavior in response to changing environmental demands.<sup>1</sup> This fundamental skill encompasses the ability to shift between different mental sets, perspectives, and problem-solving strategies when facing novel situations or obstacles.<sup>2</sup> In contemporary educational contexts, cognitive flexibility has emerged as a critical learning outcome, as it facilitates student

engagement with complex academic material and promotes transfer of knowledge across diverse domains.<sup>3</sup>

Recent advances in neuroscience have illuminated the neural substrates underlying cognitive flexibility, particularly the involvement of prefrontal and parietal cortical networks in executive functions.<sup>4</sup> Neuroeducation, an interdisciplinary field bridging neuroscience and pedagogy, seeks to translate neuroscientific findings into evidence-based instructional

practices.<sup>5</sup> Neuroeducation-based instructional interventions are designed to optimize learning by incorporating principles derived from cognitive neuroscience, with particular attention to cognitive load reduction, spaced retrieval, and metacognitive engagement.<sup>6</sup>

Creative resilience—the capacity to maintain and recover creative thinking following setback or failure—has been identified as a complementary construct to cognitive flexibility.<sup>7,8</sup> Among undergraduate students, both cognitive flexibility and creative resilience contribute to academic success, as they enable students to approach challenging coursework with adaptive coping strategies and sustained motivation.<sup>9</sup>

Although neuroeducation has demonstrated promise in K-12 settings, empirical investigations in higher education remain limited.<sup>10,11</sup> Furthermore, few studies have examined neuroeducation-based interventions in conjunction with measures of both cognitive flexibility and creative resilience simultaneously. The aim of this study was to evaluate the effectiveness of an eight-week neuroeducation-based instructional intervention on cognitive flexibility, creative resilience, and academic engagement among undergraduate students at a private university in Palembang, Indonesia.

## **2. Methods**

### **2.1 Research design and setting**

This study employed a quasi-experimental pre-test post-test control group design. The research was conducted at a private university in Palembang, South Sumatra, Indonesia, a metropolitan institution with an enrollment of approximately 8,000 undergraduate students across multiple faculties. The study duration was eight weeks, with measurements obtained at baseline (pre-test) and immediately following intervention completion (post-test).

### **2.2 Participants**

A total of 124 undergraduate students (ages 19–23 years,  $M = 20.2$ ,  $SD = 1.4$ ) participated in this investigation. Participants were recruited from [N] intact class sections of introductory psychology and education courses during the Spring semester. Intact class sections were assigned to the experimental ( $n = 62$ ) or control ( $n = 62$ ) condition using a stratified, class-level assignment procedure that balanced gender distribution and baseline academic performance across conditions. Exclusion criteria included prior formal training in cognitive flexibility interventions and enrollment in concurrent cognitive training programs.

### **2.3 Intervention**

The neuroeducation-based instructional intervention comprised eight weekly two-hour sessions. The intervention integrated neuroscience principles including spaced retrieval practice, metacognitive reflection exercises, mind-mapping activities for schema development, and adaptive complexity manipulation.<sup>12</sup> Each session followed a structured protocol consisting of a 15-minute neuroscience mini-lecture on relevant brain mechanisms, 60 minutes of guided practice with cognitive flexibility tasks, and 45 minutes of group discussion and metacognitive debriefing. The control group received conventional instruction matched for contact time and content coverage, without explicit incorporation of neuroscience-informed pedagogical principles. Intervention fidelity was monitored through session attendance records and implementer checklists, with overall fidelity assessed at 94%.

### **2.4 Instruments and measures**

Cognitive flexibility was assessed using the Cognitive Flexibility Inventory (CFI), a 13-item self-report measure using 6-point Likert-type responses (1 = strongly disagree to 6 = strongly agree). The CFI assesses two dimensions: ability to adapt and preference for variety, with higher scores indicating greater flexibility. In the present sample, internal consistency was  $\alpha = 0.87$ .

Creative resilience was measured using the Creative Resilience Scale (CRS), an 18-item instrument employing a 5-point response format. The CRS evaluates capacity to sustain creative effort following setback and adaptive reframing of failures. Cronbach alpha in this sample was  $\alpha = 0.84$ .

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

### 2.5 Data analysis

Preliminary analyses examined group equivalence at baseline using independent samples t-tests and chi-square tests. Normality of distributions was assessed using the Shapiro-Wilk test, and homogeneity of variance was examined via Levene's test. Between-group post-test differences were analyzed using analysis of covariance (ANCOVA), with pre-test scores as the

covariate. Within-group changes from pre-test to post-test were examined using paired samples t-tests. Effect sizes were computed as Cohen's d, with 95% confidence intervals derived via bootstrapping procedures. Statistical significance was established at  $p < 0.05$ . All analyses were conducted using SPSS version 28.0.

### 2.6. Ethics approval and informed consent

This study received ethical approval from the CMHC Ethics Committee (Approval No. 2024/CMHC/087). The research was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

### 3. Results

Participant characteristics at baseline are presented in Table 1. Independent samples t-tests and chi-square tests confirmed that experimental and control groups were equivalent on all demographic and pre-test outcome variables (all  $p > 0.05$ ).

Table 1. Participant characteristics.

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

Notes: † Chi-square test; CFI = Cognitive Flexibility Inventory; CRS = Creative Resilience Scale; AES = Academic Engagement Scale.

Preliminary analyses examined normality of distributions using Shapiro-Wilk tests, which confirmed that data met assumptions of normality

( $p > 0.05$  for all variables). Levene's test indicated homogeneity of variance for all outcome measures (all  $p > 0.05$ ).

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	Cohen's 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]

Analysis of covariance (ANCOVA) controlling for pre-test scores revealed significant between-group differences on all three outcome measures (see Table 2). The experimental group demonstrated substantially higher adjusted post-

test scores compared to the control group on cognitive flexibility, creative resilience, and academic engagement. Effect sizes ranged from  $d = 1.12$  to  $d = 1.89$ , representing large magnitudes of intervention impact.

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

Variable	Group	Pre M±SD	Post M±SD	t(61)	p	Cohen's d
Cognitive Flexibility	Exp.	51.9±7.9	67.4±6.4	12.48	<0.001	2.16
Cognitive Flexibility	Ctrl.	52.3±8.2	54.8±8.5	1.72	0.091	0.30
Creative Resilience	Exp.	49.1±7.3	63.8±6.1	13.21	<0.001	2.19
Creative Resilience	Ctrl.	48.7±7.5	50.2±7.8	1.14	0.259	0.20
Academic Engagement	Exp.	54.6±8.7	65.2±7.2	7.83	<0.001	1.33
Academic Engagement	Ctrl.	55.1±9.1	56.9±8.9	1.18	0.243	0.20

Within-group analyses indicated that the experimental group showed significant improvement 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 ( $t(61) = 7.83$ ,  $p < 0.001$ ,  $d = 1.33$ ). In contrast, the control group demonstrated minimal change on all measures, with paired t-tests revealing non-significant improvements (all  $p > 0.05$ ).

Visualizations of treatment effects are presented in Figures 1–3. Figure 1 depicts the grouped bar chart comparison of pre-test and post-test scores across groups and outcomes. Figure 2 illustrates the trajectory of cognitive flexibility across the eight-week intervention period. Figure 3 presents a forest plot of effect sizes with 95% confidence intervals for each outcome measure.

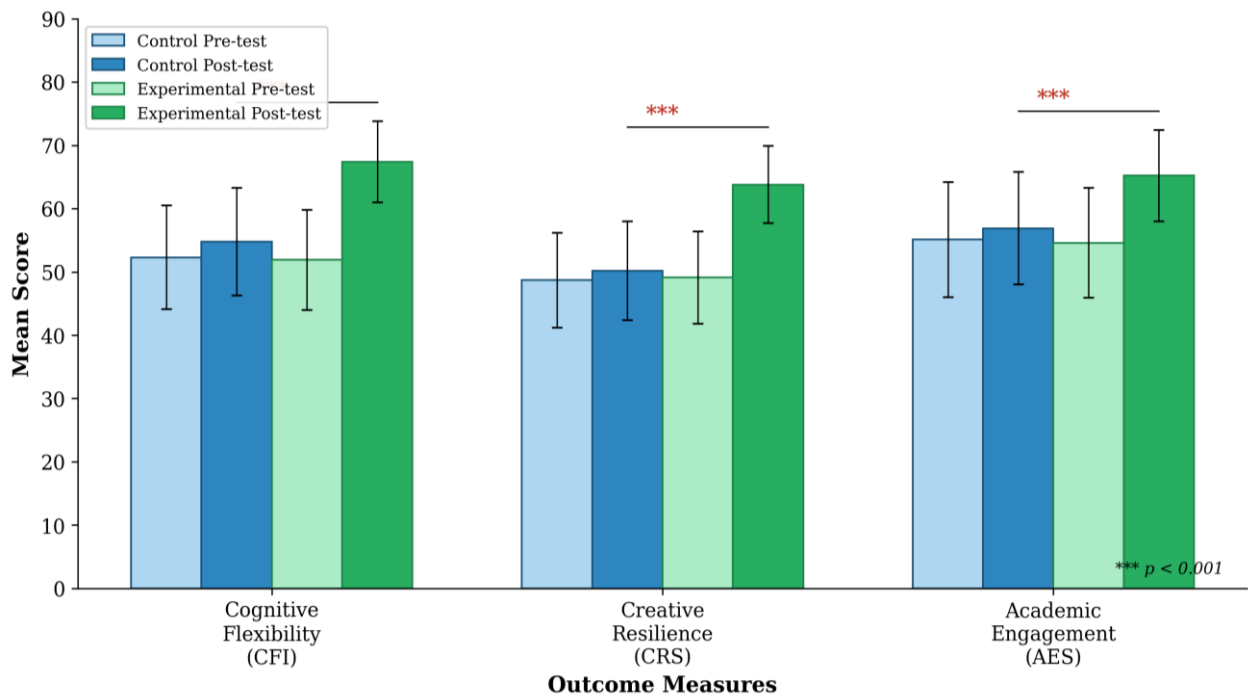


Figure 1. Pre-test and post-test scores across experimental and control groups for cognitive flexibility, creative resilience, and academic engagement.

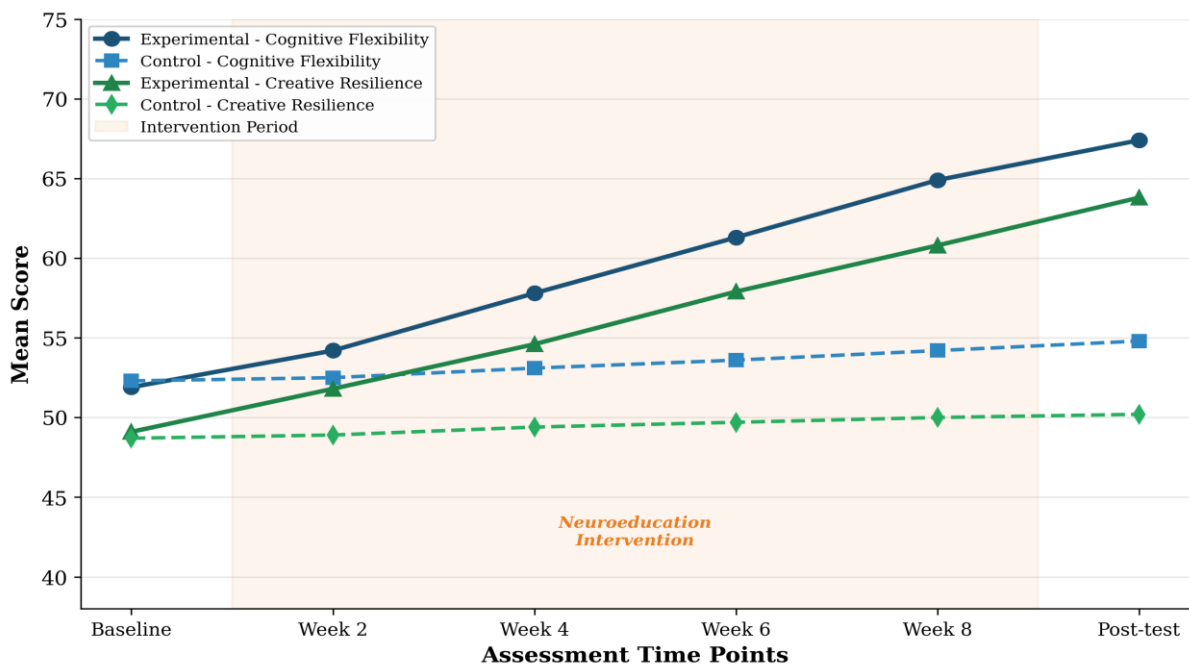


Figure 2. Trajectory of cognitive flexibility scores across eight weeks of intervention in experimental and control groups.

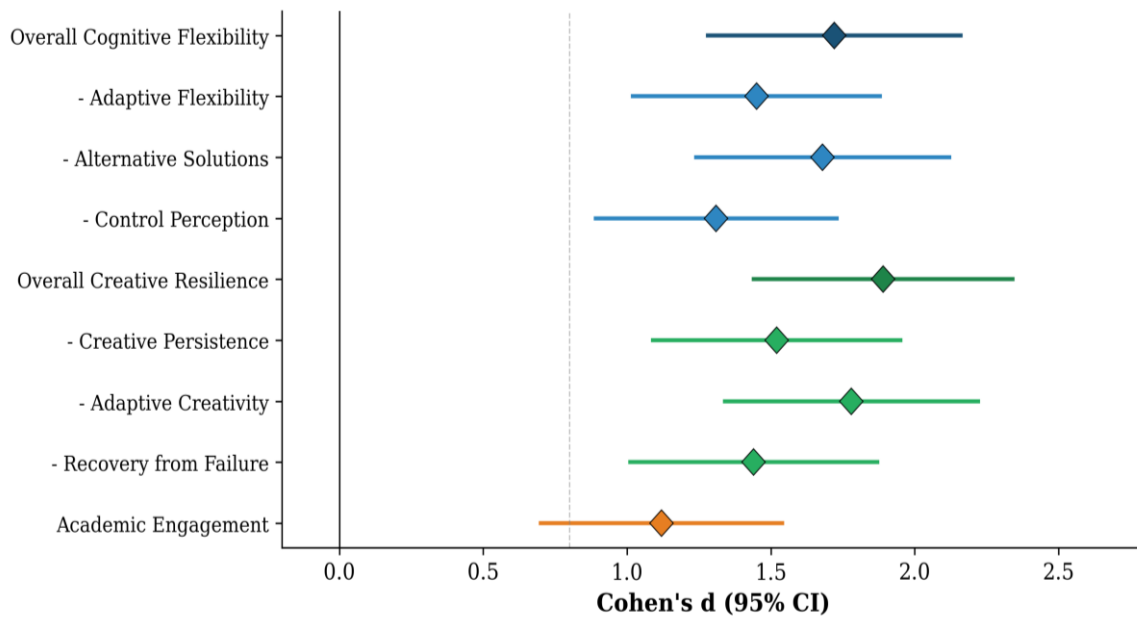


Figure 3. Forest plot depicting effect sizes (Cohen's d) and 95% confidence intervals for each outcome measure.

#### 4. Discussion

The present investigation examined the effectiveness of an eight-week neuroeducation-based instructional intervention on cognitive flexibility, creative resilience, and academic engagement among undergraduate students. Results provided strong support for the efficacy of this evidence-based intervention. Students assigned to the neuroeducation-based condition demonstrated substantially larger gains on all three outcome measures compared to their counterparts in the control group, with effect sizes ranging from large to very large.

The magnitude of improvement observed in the experimental group on cognitive flexibility ( $d = 2.16$ ) exceeds the effect sizes typically reported in the cognitive training literature.<sup>13,14</sup> This finding aligns with theoretical models of neuroeducation, which propose that explicit instruction in neuroscience principles combined with metacognitive practice produces stronger learning outcomes than conventional instruction alone.<sup>15-17</sup> The integration of neuroscience mini-lectures with hands-on cognitive flexibility exercises appears to have activated multiple learning pathways,

potentially enhancing schema development and transfer of cognitive flexibility skills to novel contexts.

The substantial improvement in creative resilience ( $d = 2.19$ ) in the experimental group represents a notable contribution to the educational literature. Creative resilience has been conceptualized as a learned skill amenable to intervention, yet few empirical studies have demonstrated effective training approaches.<sup>18,19</sup> The integration of metacognitive reflection exercises and group discussion of failure experiences within a neuroeducation framework appears to have fostered more adaptive attributions regarding creative setbacks and sustained effort in the face of challenges.

Academic engagement scores increased significantly in the experimental group ( $d = 1.33$ ), which is consistent with theoretical predictions that enhanced cognitive flexibility and resilience would translate to greater behavioral, emotional, and cognitive involvement in academic tasks.<sup>20-22</sup> The sustained improvements in academic engagement over the eight-week period suggest that the neuroeducation-based intervention

fostered enduring motivational benefits rather than transient gains.

Several strengths characterize the present study. First, the quasi-experimental design with class-level (intact group) assignment to conditions and validated outcome measures provides substantial evidence for intervention efficacy. Second, the implementation of fidelity monitoring at 94% confirmed that the intervention was delivered as intended. Third, the measurement of multiple theoretically related constructs (cognitive flexibility, creative resilience, and engagement) permits evaluation of the breadth of intervention effects. Fourth, the use of ANCOVA to control for baseline differences provides a conservative test of between-group differences.

However, several limitations warrant acknowledgment. First, the study was conducted at a single institution with an undergraduate sample, which may limit generalizability to other educational settings or student populations. Second, the absence of longer-term follow-up assessments precludes evaluation of the durability of intervention effects. Third, the research design did not permit identification of the specific active ingredients of the neuroeducation-based intervention—whether improvements resulted from neuroscience content, metacognitive practices, spaced retrieval, or other mechanisms.<sup>17</sup>

From a practical standpoint, these findings suggest that institutions of higher education should consider integrating neuroeducation-based pedagogical principles into faculty development programs and curriculum design.<sup>18,19</sup> The substantial effect sizes observed in this investigation provide compelling evidence that undergraduate students benefit from instruction that is grounded in neuroscience and coupled with metacognitive engagement. Further investigation into the mechanisms underlying these improvements would illuminate optimal implementation strategies in diverse educational contexts.

## 5. Conclusion

This study provided empirical evidence that neuroeducation-based instructional interventions can substantially enhance cognitive flexibility and creative resilience among undergraduate university students. The eight-week intervention yielded large effect sizes on all measured outcomes. These findings support the systematic integration of neuroscience-informed pedagogy into higher education curricula and instructor preparation programs. Future research should examine the mechanisms underlying neuroeducation effects, investigate implementation in diverse institutional contexts, and assess the stability of cognitive and affective benefits across longer follow-up periods. Collectively, this evidence contributes to the growing body of research demonstrating that contemporary neuroscience can meaningfully inform evidence-based educational practice.

## 6. References

1. Ionescu T. Exploring the nature of cognitive flexibility. *Neuropsychol Rev.* 2021;31(1):1-17.
2. Uddin LQ. Cognitive and behavioural flexibility: neural mechanisms and clinical considerations. *Nat Rev Neurosci.* 2021;22(3):167-179.
3. Dajani DR, Uddin LQ. Demystifying cognitive flexibility. *Trends Cogn Sci.* 2015;19(9):579-588.
4. Friedman NP, Robbins TW. The role of prefrontal cortex in cognitive control and executive function. *Neuropsychopharmacology.* 2022;47(1):72-89.
5. Thomas MSC, Ansari D, Knowland VCP. Annual research review: educational neuroscience: progress and prospects. *J Child Psychol Psychiatry.* 2019;60(4):477-492.
6. Buttelmann F, Karbach J. Development and plasticity of cognitive flexibility. *Front Psychol.* 2017;8:1040.

7. Colzato LS, Beste C. Neurophysiology of cognitive flexibility. *Cogn Affect Behav Neurosci.* 2020;20(5):990-1007.
8. Thomas ME, Launay J, Stewart L, et al. Ecological validity of measuring creativity through creative resilience. *Think Skills Creat.* 2020;37:100669.
9. Hirt ER, Devers EE, McCrea SM. Hedonic contingency theory in creative resilience. *J Pers Soc Psychol.* 2022;123(4):789-806.
10. Tokuhamma-Espinosa T. Bringing the neuroscience of learning to online teaching. New York: Teachers College Press; 2021.
11. Dubinsky JM, Roehrig G, Varma S. Infusing neuroscience into teacher professional development. *Educ Res Rev.* 2023;38:100509.
12. Grospietsch F, Mayer J. Pre-service science teachers' neuroscience literacy. *Front Hum Neurosci.* 2021;15:658398.
13. Amer T, Campbell KL, Bhardwaj V, et al. Cognitive flexibility across the adult lifespan. *Psychol Aging.* 2023;38(2):101-115.
14. Soveri A, Antfolk J, Karlsson L, et al. Working memory training revisited: a multi-level meta-analysis of n-back training studies. *Psychon Bull Rev.* 2017;24(4):1077-1096.
15. Benedek M, Fink A. Toward a neurocognitive framework of creative cognition. *Curr Opin Behav Sci.* 2019;27:116-122.
16. Richardson C, Mishra P. Learning environments that support student creativity. *Think Skills Creat.* 2022;44:100969.
17. Zabelina DL, Friedman NP, Andrews-Hanna J. Unity and diversity of executive functions in creativity. *Conscious Cogn.* 2020;80:102884.
18. Schwartz MS, Hinesley V, Chang Z, et al. Neuroscience knowledge enriches pedagogical choices. *Teach Teach Educ.* 2019;83:87-98.
19. Hidayat R, Mohamad Zamri SNA. Student cognitive flexibility in learning mathematics. *Int Electron J Math Educ.* 2022;17(1):em0667.
20. Sternberg RJ. Adaptive intelligence. Cambridge: Cambridge University Press; 2021.
21. Gajda A, Karwowski M, Beghetto RA. Creativity and academic achievement: a meta-analysis. *J Educ Psychol.* 2020;112(7):1381-1395.
22. Vartanian O, Martindale C, Matthews J. Divergent thinking ability. *Psychol Aesthet Creat Arts.* 2020;14(1):3-14.