Journal of Educational and Social Sciences **(JIPSI)**
Vol 5, No.1 April 2026
e-ISSN: 2829-2723
DOI: 10.58540/jipsi.v5i1.1458

STUDENTS' NEURO-PSYCHOLOGICAL READINESS IN THE DEEP LEARNING APPROACH: AN EXPLORATORY STUDY

Raysha Zahra Harahap[1], Chintya Angelina Sinambela[2], Yohana Imelda Tampubolon[3], Trinita Ivana Rumapea[4], Reymond Dwi Putra Sinaga[5], Dika Kristina Lambok Manurung[6], Selviana Napitupulu[7]
[1,2,3,4,5,6,7]Fakultas Keguruan dan Ilmu Pendidikan, Universitas HKBP Nommensen Pematangsiantar, Indonesia

Corresponden Email; rayshazahrahrp@gmail.com

Abstrak

Penelitian ini bertujuan untuk mengukur kesiapan neuro-psikologis siswa sebagai prasyarat untuk menerapkan pembelajaran mendalam, yang meliputi fungsi eksekutif, metakognisi, motivasi intrinsik, dan regulasi emosional, melalui dimensi pembelajaran penuh perhatian, bermakna, dan menyenangkan. Penelitian ini menggunakan pendekatan metode campuran dengan desain eksplorasi sekuensial yang didominasi oleh data kuantitatif. Penelitian ini dilakukan di SMA Negeri 1 Pematangsiantar, melibatkan sampel 130 siswa kelas X dan XI yang dipilih melalui pengambilan sampel acak bert stratified. Data kuantitatif dikumpulkan menggunakan kuesioner skala Likert 5 poin yang didasarkan pada kerangka fungsi eksekutif Diamond. Hasil menunjukkan bahwa kesiapan neuro-psikologis siswa berada dalam kategori sedang hingga tinggi, dengan rata-rata keseluruhan 3,57. Dimensi pembelajaran penuh perhatian mencatat skor tertinggi (rata-rata 3,62), diikuti oleh pembelajaran menyenangkan (3,55), dan pembelajaran bermakna (3,48). Distribusi data di seluruh dimensi dikonfirmasi normal; Namun, 12–18 persen siswa berada dalam kategori rendah, yang menunjukkan kerentanan terhadap gangguan, kesulitan dalam membangun pemahaman yang bermakna, dan ketahanan emosional yang rendah ketika menghadapi tantangan belajar. Temuan ini menunjukkan bahwa meskipun sebagian besar siswa memiliki fondasi yang memadai untuk pembelajaran mendalam, masih terdapat kesenjangan kesiapan yang berpotensi menghambat efektivitas implementasi kurikulum. Berdasarkan hasil ini, penelitian ini merekomendasikan untuk memasukkan latihan mindfulness singkat ke dalam pengajaran, memperkuat proyek lintas mata pelajaran terintegrasi yang disertai dengan strategi metakognitif, dan mengadopsi pendekatan pembelajaran yang mendorong motivasi intrinsik dan pola pikir berkembang. Selain itu, pelatihan guru berkelanjutan dalam neuropsikologi pendidikan, penilaian berkala terhadap kesiapan siswa, dan kebijakan sekolah tentang pengelolaan perangkat elektronik juga diperlukan.
Keywords: Neuro-Psikologi; Pembelajaran Mendalam; Pendidikan Menengah; Fungsi Eksekutif

Abstract

This study aims to measure students' neuro-psychological readiness as a prerequisite for implementing deep learning, encompassing executive functions, metacognition, intrinsic motivation, and emotional regulation, through the dimensions of mindful, meaningful, and joyful learning. The research employed a mixed-methods approach with a sequential exploratory design dominated by quantitative data. The study was conducted at SMA Negeri 1 Pematangsiantar, involving a sample of 130 students from grades X and XI selected through stratified random sampling. Quantitative data were collected using a 5-point Likert-scale questionnaire grounded in Diamond's executive functions framework. The results indicate that students' neuro-psychological readiness falls within the moderate-to-high category, with an overall mean of 3.57. The mindful learning dimension recorded the highest score (mean 3.62), followed by joyful learning (3.55), and meaningful learning (3.48). Data distribution across all dimensions was confirmed as normal; however, 12–18 percent of students were in the low category, indicating vulnerability to distractions, difficulties in constructing meaningful understanding, and low emotional resilience when facing learning challenges. These findings suggest that although the majority of students possess an adequate foundation for deep

learning, readiness gaps remain that could potentially hinder the effectiveness of curriculum implementation. Based on these results, the study recommends incorporating brief mindfulness exercises into teaching, strengthening integrated cross-subject projects accompanied by metacognitive strategies, and adopting learning approaches that foster intrinsic motivation and a growth mindset. Additionally, ongoing teacher training in educational neuropsychology, periodic assessment of student readiness, and school policies on device management are required.
Keywords:*Neuro-Psychological; Deep Learning; Secondary Education; Executive Functions*

INTRODUCTION

Deep learning approach in Indonesian education is currently a primary focus through the Independent Curriculum, which emphasizes in-depth learning based on three main dimensions: *mindful* (full awareness), *meaningful* (meaningful and relevant), and *joyful* (enjoyable and intrinsically motivating) (Feriyanto & Anjariyah, 2024) . This approach shifts the paradigm from rote surface learning to a process involving in-depth reflection, conceptual connections to real-life situations, and positive emotional engagement, so that students not only master the material but also develop critical thinking, creativity, and resilience (Laana & Sondopen, 2020). However, the success of *deep learning* is largely determined by students' neuropsychological readiness, namely the ability of the brain's executive functions (such as sustained attention, *working memory* , *impulse inhibition* , and emotional regulation) and intrinsic motivation that supports complex cognitive processes (Barenberg et al., 2011) . At the high school level, where *the maturation of the prefrontal cortex* is still ongoing, this readiness is crucial to avoid the frustration, boredom, or shallow understanding that often arise during curricular transitions.

The study of students' neuropsychological readiness is increasingly important amidst the challenges of post-pandemic education, where students face excessive digital distractions, academic pressure, and cognitive decline, as reflected in Indonesia's low PISA 2022 scores in reading, mathematics, and creative thinking. Without adequate readiness—including *mindful* focus, *meaningful connections* for concept elaboration, and *joyful experiences* for emotional resilience— *deep learning* risks suboptimal outcomes, leading to inequitable *outcomes* and increased student mental stress. At SMA Negeri 1 Pematangsiantar, as a school actively adopting elements of the Independent Curriculum, this study is relevant for empirically uncovering students' neuropsychological profiles, providing a basis for neuroscience-based interventions that can enhance the effectiveness of deep learning in the local context of North Sumatra (Rainy & Chowdhury, 2022).

Several relevant previous studies have provided a strong foundation, such as Feriyanto's (2024) study, which, through library research, found that *deep learning* is effective when it integrates *mindful*, *meaningful*, and *joyful* learning to enhance students' in-depth understanding. A study by Schonert-Reichl et al. (2015) empirically demonstrated that a school-based *mindful* learning program improves elementary school students' executive function, emotional regulation, and well-being, which are prerequisites for readiness for deep learning. Furthermore, studies in Indonesia by Arthadewi et al. (2025) and Mutmainnah & Adrias (2025) demonstrated empirical evidence that a mindful - *meaningful* - *joyful deep learning approach* increases student active participation and motivation, although it is still hampered by teacher readiness and infrastructure. Neuroeducational studies such as those by Diamond (2013) also confirm the role of executive functions as a predictor of school readiness, while Willis (2007) links *joyful* education with the activation of the brain's reward system for sustained motivation. Thus, this exploratory study fills the empirical gap at the Indonesian high school level with contextual data, serving as a reference for the development of neuropsychological strategies in deep learning (Harvianto, 2021).

This study aims to explore the level of neuropsychological readiness of students at SMA Negeri 1 Pematangsiantar in a *deep learning approach* , focusing on the dimensions of *mindful, meaningful*, and *joyful learning* through measuring executive function and emotional regulation. This study is expected to contribute to a deeper understanding of how students' neuropsychological readiness can be optimized, not only to improve academic achievement but also mental well-being in an era of education that increasingly demands deep and adaptive thinking. Through this exploratory approach, the findings can provide practical recommendations for schools and policymakers in strengthening the implementation of *deep learning* based on neuroscience evidence.

METHOD

This study used a *mixed methods approach* with quantitative dominance and qualitative support in a *sequential exploratory design* . The research location was SMA Negeri 1 Pematangsiantar, North Sumatra, with a population of all students in grades X and XI of the 2025/2026 academic year. A sample of 130 students was selected through a *stratified random sampling technique* based on class and major to ensure equitable representation. Quantitative data collection was carried out through a 5-point Likert scale-based *self-report questionnaire* consisting of 40 items, adapted from standardized instruments such as *the Behavior Rating Inventory of Executive Function (BRIEF), Metacognitive Awareness Inventory (MAI), Intrinsic Motivation Inventory (IMI), and Growth Mindset Scale* , with a focus on four subscales: executive function, metacognition & *self-regulated learning,* intrinsic motivation & *growth mindset* , and emotional regulation & resilience (Dörrenbächer-Ulrich & Bregulla, 2024) . Qualitative data were collected through semi-structured interviews with 15–20 students purposively selected based on extreme scores (high and low) to deepen understanding of the context. Quantitative data analysis included descriptive statistics (mean, standard deviation, percentage of readiness categories: low <3.0, medium 3.0–4.0, high >4.0), Shapiro-Wilk normality test, and proxy item mapping to measure the dimensions of *mindful, meaningful*, and *joyful learning* . Theoretically, the analysis was based on Diamond's (2013) educational neuropsychology framework for executive function as a predictor of school readiness. Mixed methods data integration was carried out through triangulation to strengthen the validity of the findings, with instrument validity testing through expert judgment and pilot testing (Cronbach's Alpha >0.70), so that the results can comprehensively describe students' neuropsychological readiness in the context of *deep learning*.

RESULTS AND DISCUSSION

Neuropsychology in Education: Conceptual and Theoretical Approaches

Neuropsychology in education, often referred to as *educational neuroscience*, is an interdisciplinary field that integrates findings from cognitive neuroscience, developmental psychology, and pedagogical practices to understand how brain processes support or hinder learning (Williamson et al., 2025) . Conceptually, educational neuropsychology starts from the premise that learning is not merely a behavioral or cognitive phenomenon, but rather a neurological process involving brain plasticity (*neuroplasticity*), specific neural networks (such as *the prefrontal cortex* for executive function, *the hippocampus* for memory, and the amygdala for emotional processing), and dynamic interactions between biological, psychological, and environmental factors. This approach rejects the reductionist view that only sees the brain as a "black box," but instead emphasizes that understanding neural mechanisms can inform more effective teaching strategies, personalized learning, and early intervention for learning difficulties (Thomas et al., 2019) .

Theoretically, educational neuropsychology rests on several key frameworks. First, the Hebbian neuroplasticity theory (" *neurons that fire together, wire together* "), further developed by Donald Hebb (1949) and supported by modern empirical evidence, asserts that repeated and meaningful learning experiences can change brain structure and connectivity throughout life (Yeatman & Yablonski, 2025) . This theory underpins the concept that education is not simply a transfer of knowledge but actively shapes students' neural architecture. Second, Diamond's (2013) executive function model identifies three core components— *inhibitory control, working memory* , and *cognitive flexibility* —as key predictors of academic success, as these components rely on the maturation of *the prefrontal cortex* , which continues into the early 20s. Third, the theory *of embodied cognition* and *situated learning* emphasizes that learning is not isolated in the brain, but rather integrated with the body, emotions, and social context, so that a neuropsychological approach must consider emotional regulation (*amygdala-prefrontal interplay*) and intrinsic motivation (*dopamineergic reward system*) (Thomas & Arslan, 2025) .

In the context of contemporary education, neuropsychology provides a foundation for addressing persistent neuromyths, such as "we only use 10% of our brains" or "the rigid visual-auditory-kinesthetic learning style," while promoting *evidence-based practices* . For example, the principles of *spaced repetition* and *retrieval practice* are supported by *neuroimaging evidence* showing the strengthening of long-term memory consolidation in the hippocampus (Ashton, 2015) . Furthermore, this approach is increasingly relevant in the digital and post-pandemic era, where high cognitive load from digital *multitasking* can impair executive function, necessitating *mindful learning designs that address working memory* capacity (*Sweller's cognitive load theory* , which is linked to neural activity). Educational neuropsychology also opens up space for *targeted interventions* , such as *mindfulness training* , which has been shown to increase prefrontal cortex thickness and reduce amygdala reactivity, or *growth mindset programs* that alter the brain's response patterns to errors (*error-related negativity on the EEG*) (Ecklund-Johnson & Pearson, 2019) .

By understanding that each student has a unique neural profile—influenced by genetics, early experiences, and environment—educators can design learning that is not only academically effective but also supports optimal brain development, emotional resilience, and long-term psychological well-being. This approach bridges the gap between “what we teach” and “how students’ brains learn,” moving education toward a more precise, inclusive, and neuroscience-based evidence-based learning environment.

Dimensions of Mindful Learning

mindful dimension in the *deep learning approach* refers to students' ability to learn with full awareness (*mindfulness*), which is a mental state that involves focused attention on the present moment, without over-judgment, as well as metacognitive awareness of one's own thought processes, thus enabling more reflective learning that is not disturbed by internal or external distractions (Langer, 1993) . Conceptually, *mindful Learning* is a key pillar *of deep learning* because it encourages students to not only passively receive information, but to actively observe, feel, and reflect on their learning experiences, ultimately resulting in deeper and more meaningful understanding. Theoretically, this dimension is based on the principle of *mindfulness from the contemplative tradition integrated into education by Kabat-Zinn (1994) and developed in the school context through the Mindful Education* model. (Soloway, 2016) , where *mindfulness* improves the brain's executive functions—particularly *attentional control* and *inhibitory control* —by strengthening *prefrontal cortex connectivity.* (Suwandi et al., 2024) .

In addition, *cognitive psychology theories* such as *Attention Restoration Theory* (Ohly et al., 2016) , explains that *mindful practice can restore directed attention* capacity that is often depleted due to exposure to digital distractions, while in the neuroeducational framework, neuroimaging evidence shows that regular *mindful practice* increases prefrontal cortex thickness and reduces amygdala reactivity, so that students are better able to maintain sustained focus when facing complex material, reduce boredom, and increase cognitive resilience—all essential elements for successful *deep learning* that demands active engagement, deep reflection, and conscious and enjoyable learning.

Table 1. Results of Students' Mindful Test

Statistics	Mark	Interpretation
Average Score (Mean)	3.62	Medium-High
Standard Deviation (SD)	0.68	Medium variation
Low Percentage (<3.0)	12.3%	Prone to distraction
Medium Percentage (3.0–4.0)	58.5%	Just focus on deep learning
High Percentage (>4.0)	29.2%	Very *mindful* and concentrated
Normality Test (Shapiro-Wilk p-value)	0.082 (>0.05)	Normal distribution

Mindful dimension *Learning readiness* among students at SMA Negeri 1 Pematangsiantar showed a moderate-high level of readiness with an average score of 3.62, reflecting a fairly good ability to maintain full awareness, sustained focus, and cognitive flexibility when facing in-depth learning. The main factors supporting this readiness are a relatively conducive school environment, structured learning routines, and the positive influence of the digital native generation who are accustomed to light multitasking through everyday gadgets. In addition, exposure to teaching methods that begin to integrate elements of reflection and group discussions also train students to be more aware of their own thinking processes, so that 58.5% of students are in the moderate category and 29.2% in the high category.

However, the score variation, indicated by a standard deviation of 0.68, and the presence of 12.3% of students in the low category, indicates several contributing factors. The primary causes are high levels of external and internal distractions, such as distractions from social media, phone notifications, and wandering thoughts due to fatigue or academic overload. Other factors include a lack of explicit practice in *mindfulness techniques* or sustained concentration in class, as well as the influence of a less conducive home environment (e.g., family distractions or unlimited internet access). Students in the low category tend to be prone to boredom when material requires prolonged concentration, which can hinder their ability to fully engage in deep learning approaches.

The normal distribution of the data (Shapiro-Wilk p-value 0.082 > 0.05) confirms that this pattern *of mindfulness readiness is evenly distributed across the sample population, with no extreme deviations. This finding implies that although the majority of students already have an* adequate *mindfulness foundation, targeted interventions such as brief mindfulness* training , creating a distraction-free learning environment, and integrating mindfulness exercises into the curriculum can further reduce the proportion of low-performing students and increase the overall effectiveness of *deep learning implementation.*

Dimensions of Meaningful Learning

meaningful dimension in the *deep learning approach* refers to a learning process in which students actively connect new knowledge with pre-existing experiences, concepts, and knowledge schemas, resulting in meaningful, real-life, and long-term understanding, rather than mere surface memorization. Conceptually, *meaningful learning* emphasizes the construction of personal knowledge through elaboration, organization, and integration of information, where students do not just passively receive facts, but rather build a holistic network of meaning that can be applied in new contexts, thus encouraging knowledge transfer and creative problem solving (Bakosh et al., 2016) . Theoretically, this dimension is firmly rooted in the theory *of Meaningful Learning* (Sexton, 2025) which states that meaningful learning occurs when new material is subsumed into existing cognitive structures through advance organizers and hierarchical connections, and is supported by Vygotsky's social constructionism which emphasizes the role of social interaction in building shared meaning (Sexton, 2025) .

Within the neuroeducational framework, this process involves activating the hippocampus for long-term declarative memory consolidation and *the prefrontal cortex* for planning and organizing ideas, where *neuroimaging evidence* suggests that relevant and emotional learning experiences strengthen neural synapses through the *long-term potentiation* (LTP) mechanism. Furthermore, *Cognitive Load Sweller's* (1988) theory complements this by asserting that *meaningful* learning reduces *extraneous load* while increasing *germane load, allowing working memory* capacity to be focused on forming meaningful schemas; in the context of modern *deep learning* , this dimension becomes essential because it requires students to continuously search for the "why" and "how" behind concepts, resulting in not only higher retention, but also critical, innovative, and adaptive thinking skills that are in line with the demands of the 21st century (Paas et al., 2010) .

Table 2. Results of Students' Meaningful Test

Statistics	Mark	Interpretation
Average Score (Mean)	3.48	Currently
Standard Deviation (SD)	0.74	Medium-high variation
Low Percentage (<3.0)	18.5%	Difficulty associating meaningful concepts
Medium Percentage (3.0–4.0)	60.0%	Quite good at organizing ideas
High Percentage (>4.0)	21.5%	Highly capable of making deep connections
Normality Test (Shapiro-Wilk p-value)	0.056 (>0.05)	Normal distribution

Meaningful dimensions *The learning ability* of students at SMA Negeri 1 Pematangsiantar is at a moderate level with an average score of 3.48, indicating that most students are quite capable of making meaningful connections between new material and existing knowledge and organizing ideas systematically to achieve deep understanding. The main supporting factor is daily learning experiences that begin to integrate projects, discussions, and real-life application-based assignments, which train students to plan steps and link concepts contextually. Furthermore, the influence of teachers who use an Independent Curriculum approach—with an emphasis on learning based on life phenomena—contributes to strengthening this ability, so that 60.0% of students are in the moderate category and 21.5% in the high category.

A standard deviation of 0.74, classified as medium-high, and a proportion of 18.5% of students in the low category revealed significant variation in readiness. The main causes of difficulties in the low group were limited working memory and minimal planning experience, often due to the dominant rote learning pattern in the past, a lack of explicit practice in creating concept maps or meaningful summaries, and a fragmented workload that made it difficult for students to see connections between topics. Environmental factors such as a lack of parental support in guiding knowledge connections or exposure to material that was too theoretical without application also contributed to these obstacles.

The normal distribution of scores (Shapiro-Wilk p-value 0.056 > 0.05) indicates that the level of readiness *for meaningful learning* is naturally distributed across the sample without extreme outliers. This finding implies that although the majority of students already have an adequate foundation for *meaningful* learning, interventions such as metacognitive strategy training (*mind mapping, questioning,* and *connecting*), increased integrated project assignments, and individual mentoring for lower-category students will be very effective in strengthening this dimension in the overall implementation *of deep learning .*

Joyful Learning Dimension

The joyful learning dimension in *the deep learning approach* refers to a learning experience that is enjoyable, intrinsically satisfying, and full of joy, where students feel naturally motivated because the learning process itself feels meaningful, challenging yet *achievable* , and provides a deep sense of achievement and emotional satisfaction, thus transforming learning from an obligation into an enjoyable activity (Anggoro et al., 2017) . Conceptually, *joyful* learning emphasizes the role of positive emotions as a catalyst for sustained engagement, where feelings of pleasure, curiosity, and flow state encourage students to engage longer and more intensely without external coercion, thereby increasing resilience to adversity and strengthening long-term knowledge retention. Theoretically, this dimension is rooted in *Self-Determination Theory.* (Deci, Edward L., 2012) which emphasizes that intrinsic motivation grows when basic *psychological needs—autonomy, competence* , and *relatedness* —are met, thus producing *joyful* experiences through a sense of autonomy in learning, mastery of challenges, and supportive social relationships; in addition, the *Flow theory Csikszentmihalyi* (1990) complements this by describing the optimal condition when challenge is balanced with ability, resulting in total immersion accompanied by joy and loss of awareness of time (Beard, 2015) .

From a neuroeducational perspective, *joyful* learning involves the activation of the dopaminergic reward system (*mesolimbic pathway*) which reinforces learning behavior through the release of dopamine upon achievement or new discoveries, while positive emotions reduce cortisol stress that can inhibit the hippocampus; empirical evidence from neuroimaging suggests that *joyful learning experiences increase prefrontal-amygdala* connectivity , making students more resilient to frustration and better able to maintain intrinsic motivation—crucial elements in *deep learning* that require long-term persistence, deep reflection, and full emotional engagement to achieve holistic understanding and ongoing personal development.

Table 3. Results of the Student Joyful Test

Statistics	Mark	Interpretation
Average Score (Mean)	3.55	Medium-High
Standard Deviation (SD)	0.81	High variation
Low Percentage (<3.0)	15.4%	Easily frustrated when learning is difficult
Medium Percentage (3.0–4.0)	55.4%	Just be resilient and enjoy the process
High Percentage (>4.0)	29.2%	Very *joyful* and motivated
Normality Test (Shapiro-Wilk p-value)	0.104 (>0.05)	Normal distribution

joyful learning dimension of students at SMA Negeri 1 Pematangsiantar showed a medium-high level of readiness with an average score of 3.55, indicating that the majority of students were quite resilient in facing learning challenges and were able to enjoy the in-depth learning process without being overly burdened by negative emotions. Key supporting factors included a relatively positive school environment, social support from peers and teachers that encouraged collaboration and appreciation for effort, and the influence of a younger generation accustomed to gamification elements or fun digital content in their daily lives. Furthermore, the initial implementation of the Independent Curriculum approach, which emphasized interestbased learning and creative projects, also increased feelings of joy and intrinsic motivation, resulting in 55.4% of students falling into the medium category and 29.2% into the high category.

The high standard deviation (0.81) and the proportion of 15.4% of students in the low category reflect considerable variation in emotional experiences during learning. The main causes in the low group are easily frustrated due to high academic pressure (such as grade targets or exams), a lack of successful experience in difficult tasks that leads to a lack of confidence, and the influence of external factors such as physical fatigue, personal problems, or a lack of emotional support from the family environment. These students tend to be impulsive in the face of mistakes or difficulties, which reduces the *joyful aspect* and makes the learning process feel more like a burden than a pleasure.

The normal distribution of scores (Shapiro-Wilk p-value 0.104 > 0.05) confirmed that the *joyful* learning readiness pattern was evenly distributed without significant deviations across the sample. This finding suggests that although most students already possess sufficient emotional resilience for *joyful* learning, interventions such as growth mindset development programs, emotion regulation techniques (e.g., *breathing exercises* or positive reflection *journaling*), and learning designs that integrate more fun and reward elements will be effective in reducing the proportion of low-performing students and increasing the overall enjoyable learning experience in the deep learning approach.

Students' Neuro-Psychological Readiness in the Deep Learning Approach

The overall neuropsychological readiness of students at SMA Negeri 1 Pematangsiantar is classified as medium-high, with a strong foundation of executive function to support the implementation of *deep learning* at the school. This school has demonstrated positive initial practices through structured learning routines, integration of Independent Curriculum elements such as projects and contextual discussions, and a relatively supportive social environment, reflected in the ability of the majority of students to maintain *mindful focus* , make *meaningful connections* , and enjoy the *joyful process* despite facing challenges. However, the relatively high variation in scores and the proportion of students in the low category (12–18%) indicate gaps, especially among students who are still vulnerable to digital distractions, residual memorization patterns, and emotional frustration due to academic pressure, so the school has not fully optimized in creating an equitable and neuropsychologically resilient learning ecosystem.

Practically, schools can begin strengthening *mindfulness* by integrating brief mindfulness exercises (e.g., 5–10 minutes of *mindful* breathing or mindful practice at the beginning of a lesson) and gadget management policies during class time to reduce distractions. Theoretically, this step aligns with *Attention Restoration Theory* and neuroplasticity evidence showing that regular *mindfulness practice* strengthens prefrontal attentional control, better preparing students for the deep reflection that is at the heart of deep learning.

For the *meaningful dimension*, schools need to improve practices with more integrated project-based assignments, the use of *advanced organizers* such as *mind mapping* or *KWL charts* (*Know-Want-Learn*), and collaboration between subjects so that students are trained to connect concepts meaningfully. This approach is theoretically supported by Ausubel's theory of subsumption and *cognitive load management*, which ensures *working memory* is focused on germane elaboration, thereby reducing the difficulty of organizing ideas in low-level students and improving knowledge transfer holistically.

Meanwhile, in the *joyful dimension* , concrete steps that can be taken immediately include implementing light gamification elements, providing autonomy in task choices, and appreciating the process through *growth mindset feedback* and celebrating small achievements, accompanied by simple emotional regulation sessions such as positive reflection *journaling* . Theoretically, this practice is based on *Self-Determination Theory* and *Csikszentmihalyi's flow mechanism*, which stimulates the dopaminergic *reward system* and reduces the impact of cortisol stress, so that schools can build a learning culture that is not only deep but also enjoyable and resilient.

CONCLUSION

This exploratory study concludes that students at SMA Negeri 1 Pematangsiantar have a positive neuropsychological readiness. Furthermore, strategic and practical steps are needed through initial implementation of the Independent Curriculum, which supports sustained focus, meaningful conceptual connections, and intrinsic motivation, so that the majority of students are able to actively and resiliently engage in deep learning. However, school capacity is needed, indicating that readiness is not yet fully distributed, with the main obstacles being digital distractions, residual memorization patterns, and emotional vulnerability to challenges. This reflects the need for systematic reinforcement so that *deep learning* can be implemented optimally and inclusively for all students. Therefore, SMA Negeri 1 Pematangsiantar needs to immediately implement concrete steps in developing ongoing teacher training and regularly monitoring students' neuropsychological profiles. Thus, *deep learning* is not merely a formal curricular approach, but a true learning transformation that supports holistic brain development, increases resilience, intrinsic motivation, and long-term academic achievement, while preparing students for the complexities of 21st-century education.

REFERENCE

Anggoro, S., Sopandi, W., & Sholehuddin, M. (2017). Influence of Joyful Learning on Elementary School Students' Attitudes Toward Science. *Journal of Physics: Conference Series*, *812*, 012001. https://doi.org/10.1088/1742-6596/812/1/012001

Ashton, R. (2015). Educational Neuropsychology. In H. Reed, J., Byard, K., Fine (Red), *Neuropsychological Rehabilitation of Childhood Brain Injury* (bll 237–253). London: Palgrave Macmillan UK. https://doi.org/10.1057/9781137388223_12

Bakosh, L. S., Snow, R. M., Tobias, J. M., Houlihan, J. L., & Barbosa-Leiker, C. (2016). Maximizing Mindful Learning: Mindful Awareness Intervention Improves Elementary School Students' Quarterly Grades. *Mindfulness*, *7*(1), 59–67. https://doi.org/10.1007/s12671-015-0387-6

Barenberg, J., Berse, T., & Dutke, S. (2011). Executive functions in learning processes: Do they benefit from physical activity? *Educational Research Review*, *6*(3), 208–222. https://doi.org/10.1016/j.edurev.2011.04.002

Beard, K. S. (2015). Theoretically Speaking: An Interview with Mihaly Csikszentmihalyi on Flow Theory Development and Its Usefulness in Addressing Contemporary Challenges in Education. *Educational Psychology Review*, *27*(2), 353–364. https://doi.org/10.1007/s10648-014-9291-1

Deci, Edward L., and R. M. R. (2012). Self-determination theory. *Handbook of theories of social psychology*, *1*(20), 416–436.

Dörrenbächer-Ulrich, L., & Bregulla, M. (2024). The Relationship Between Self-Regulated Learning and Executive Functions—a Systematic Review. *Educational Psychology Review*, *36*(3), 95. https://doi.org/10.1007/s10648-024-09932-8

Ecklund-Johnson, E., & Pearson, C. M. (2019). Foundations of Contemporary Neuropsychology. In E. E. and S. D. G. Caleb M. Pearson (Red), *Neurosurgical Neuropsychology* (bll 27–37). London: Elsevier. https://doi.org/10.1016/B978-0-12-809961-2.00003-5

Feriyanto, F., & Anjariyah, D. (2024). Deep Learning Approach Through Meaningful, Mindful, and Joyful Learning: A Library Research. *Electronic Journal of Education, Social Economics and Technology*, *5*(2), 208–212. https://doi.org/10.33122/ejeset.v5i2.321

Harvianto, Y. (2021). Pengaruh Media Pembelajaran Interaktif Terhadap Hasil Belajar Pendidikan Jasmani Selama Masa Pandemi Covid-19. *Jurnal Porkes*, *4*(1), 1–7. https://doi.org/10.29408/porkes.v4i1.3485

Laana, D., & Sondopen, D. (2020). Keterampilan Guru Pendidikan Agama Kristen Untuk Meningkatkan Minat Belajar Murid Di Kelas. *Excelsis Deo: Jurnal Teologi, Misiologi, dan Pendidikan*, *2*(2), 27–32. https://doi.org/10.51730/ed.v2i2.47

Langer, E. J. (1993). A Mindful Education. *Educational Psychologist*, *28*(1), 43–50. https://doi.org/10.1207/s15326985ep2801_4

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, *19*(7), 305–343. https://doi.org/10.1080/10937404.2016.1196155

Paas, F., van Gog, T., & Sweller, J. (2010). Cognitive Load Theory: New Conceptualizations, Specifications, and Integrated Research Perspectives. *Educational Psychology Review*, *22*(2), 115–121. https://doi.org/10.1007/s10648-010-9133-8

Rainy, T. A., & Chowdhury, A. R. (2022). The Role Of Artificial Intelligence In Vendor Performance Evaluation Within Digital Retail Supply Chains: A Review Of Strategic Decision-Making Models. *American Journal of Scholarly Research and Innovation*, *01*(01), 220–248. https://doi.org/10.63125/96jj3j86

Sexton, S. S. (2025). Meaningful Learning—David P. Ausubel. In T. J. Akpan, B., Kennedy (Red), *Science Education in Theory and Practice. Springer Texts in Education* (bll 157–171). Cham. https://doi.org/10.1007/978-3-031-81351-1_10

Soloway, G. B. (2016). Preparing Teacher Candidates for the Present: Investigating the Value of Mindfulness-Training in Teacher Education. In R. Schonert-Reichl, K., Roeser (Red), *Handbook of Mindfulness in Education. Mindfulness in Behavioral Health* (bll 191–205). New York: Springer. https://doi.org/10.1007/978-1-4939-3506-2_12

Suwandi, Putri, R., & Sulastri. (2024). Inovasi Pendidikan dengan Menggunakan Model Deep

Learning di Indonesia. *Jurnal Pendidikan Kewarganegaraan dan Politik*, *2*(2), 69–77. https://doi.org/10.61476/186hvh28

Thomas, M. S. C., & Arslan, Y. (2025). Why does the brain matter for education? *British Journal of Educational Psychology*, *95*(2), 303–320. https://doi.org/10.1111/bjep.12727

Thomas, Michael S. C., Ansari, D., & Knowland, V. C. P. (2019). Annual Research Review: Educational neuroscience: progress and prospects. *Journal of Child Psychology and Psychiatry*, *60*(4), 477–492. https://doi.org/10.1111/jcpp.12973

Williamson, B., Pykett, J., & Kotouza, D. (2025). Learning brains: educational neuroscience, neurotechnology and neuropedagogy. *Pedagogy, Culture & Society*, 1–21. https://doi.org/10.1080/14681366.2025.2521458

Yeatman, J. D., & Yablonski, M. (2025). The Virtuous Cycle between Education and Neuroscience. *Mind, Brain, and Education*, *19*(4), 365–375. https://doi.org/10.1111/mbe.70017