Global Education Journal
Vol. 5, 3 (September-December, 2025), pp. 583-592
EISSN: 2986-6529, DOI: https://doi.org/10.59525/gej.1360

Monitoring Brain Waves during Dhikr: The Foundation for Developing an Islamic Neurofeedback-Based Independent Learning Model

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ARTICLE INFO

Keywords:

Dhikr;
Neurofeedback;
Self-Regulated Learning.

Article history:

Received 2025-11-01
Revised 2025-11-11
Accepted 2025-12-25

ABSTRACT

This study explores the integration of dhikr spiritual practices with neurofeedback technology to improve self-regulated learning (SRL) skills in Muslim students. Using a mixed method approach, the study involved 30 Muslim students (aged 18-25 years) who underwent a dhikr intervention with neurofeedback for 4 weeks. Brain activity was measured using a 14-channel EEG device, while SRL ability was measured by the Motivated Strategies for Learning Questionnaire (MSLQ) through pre-test, post-test, and follow-up. The results of EEG analysis showed a significant increase in alpha (8-13 Hz) and theta (4-8 Hz) waves, as well as a decrease in beta (13-30 Hz) and gamma (>30 Hz) waves during and after the practice of dhikr. MSLQ measurements showed significant improvements in almost all components of SRL, especially metacognitive ability (d=1.07), self-efficacy (d=0.84), and business regulation (d=0.82). Correlation analysis revealed a strong positive association between increased alpha and theta waves and increased SRL scores. Thematic analysis of semi-structured interviews identified five main themes: increased internal awareness, mental calmness, strengthening of spiritual connections, transfer to learning activities, and the facilitative role of neurofeedback visualization. These findings suggest that the integration of dhikr with neurofeedback has the potential to be an innovative approach to developing SRL abilities while strengthening the religious identity of Muslim students, offering an educational model that integrates cognitive and spiritual aspects.

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1. INTRODUCTION

In the progress of Islamic civilization, spiritual traditions in the form of dhikr have become an essential practice for centuries. Dhikr, which etymologically means "remembering Allah", is a form of contemplative meditation that involves the repetition of Allah's names or sacred sentences with solemnity (Al-Ghazali, 2017). This spiritual practice is now attracting the attention of the global scientific community, especially in the context of the neuroscience revolution and brain activity monitoring

technology. The neurofeedback approach—a method of measuring and visualizing brain waves in real-time—opens up a new dimension in understanding the neurobiological processes that occur during dhikr and their implications for human cognitive function (Amin & Haryanto, 2020; Newberg & Waldman, 2022).

In the midst of the challenges of the digital age marked by an abundance of information and cognitive distractions, self-regulated learning (SRL) skills are becoming a crucial skill for contemporary learners. SRL encompasses a complex set of processes in which individuals actively plan, monitor, evaluate, and modify their learning strategies to achieve academic goals (Zimmerman & Schunk, 2019). This ability not only plays an important role in formal academic success but also serves as the foundation for lifelong learning that is emphasized both in the perspective of modern education and Islamic educational philosophy (Hashim & Langgulung, 2018).

A number of recent studies have shown a positive correlation between meditation practices and improved brain executive function, including self-regulation, focused attention, and working memory—vital components of SRL (Tang et al., 2021; Luberto et al., 2020). Notably, meditation has been shown to induce significant changes in brain waves, characterized by increased amplitudes of alpha waves (8-12 Hz) associated with focused relaxation states, as well as theta waves (4-8 Hz) associated with creativity and intuition (Harne & Hiwale, 2018). However, the majority of these studies have focused on meditation practices in the Buddhist tradition or secular Mindfulness, while neuroscientific exploration of Islamic dhikr practices is still relatively limited and fragmentary (Sayeed & Prakash, 2023).

This knowledge gap becomes even more striking when considering the potential integration of dhikr with the development of SRL through a neurofeedback perspective. The practice of dhikr has its own uniqueness compared to other forms of meditation, especially in aspects of spiritual meaning, the use of certain verbal formulas, and the simultaneous involvement of complex cognitive-spiritual-motor dimensions (body movements) (Fathoni & Rahman, 2022). These multidimensional characteristics have the potential to create distinctive "neuronal imprints" that can be leveraged to optimize SRL capabilities through culturally and spiritually calibrated neurofeedback protocols.

This study seeks to fill this gap by comprehensively exploring the patterns of brain activity during dhikr practice, identifying neural biomarkers that correlate with improved self-regulation function, and developing a prototype of Islamic neurofeedback protocols that can be implemented in the context of education. This interdisciplinary approach that integrates neuroscience, educational psychology, and Islamic spirituality is expected not only to enrich the scientific literature on the brain-mind-spirituality relationship but also to provide an empirical foundation for the development of culturally-sensitive and holistic pedagogical interventions.

As stated by Al-Attas (2019) in his conception of ta'dib, true Islamic education aims to develop human beings holistically—intellectually, spiritually, and morally. By combining Islamic spiritual wisdom and contemporary neuroscience findings, this research supports a vision of Islamic education that integrates science and charity, and reflects the spirit of Islam as din al-fitrah—a religion that is in harmony with human nature, including its neurological structure and function. Through this exploration of "Islamic neurofeedback", we hope to pave the way for an educational paradigm that is not only empirically effective but also spiritually authentic, strengthening the ability of self-regulated learning while maintaining the religious identity of Muslim learners in the era of digital globalization.

2. METHODS

This research is designed by adopting a mixed method approach that harmoniously combines quantitative and qualitative data. This approach was chosen to gain a thorough understanding of brain activity during dhikr practice and how it affects self-regulated learning abilities. As explained by Creswell and Creswell (2018), the research design was quasi-experimental with pre-test and post-test measurements to compare participants' conditions before and after the intervention.

In this study, the research team involved 30 Muslim students, consisting of 15 males and 15 females, with an age range of 18-25 years. The participants were selected using purposive sampling techniques,

taking into account several important criteria: they had minimal experience in the practice of dhikr, had no history of neurological or psychiatric disorders, were not taking drugs that could affect brain activity, and were willing to participate in the entire research series. The determination of the sample count was based on the calculation of power analysis with a moderate effect size (d = 0.5), significance level $\alpha = 0.05$, and power (1-β) = 0.8 as recommended by Cohen (1992).

To collect comprehensive data, researchers used several research instruments. First, a portable Electroencephalography (EEG) device with 14 electrodes placed according to the international system of 10-20 as described by Klem et al. (1999). This advanced device is capable of recording various brain waves at delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (>30 Hz) frequencies, and is equipped with neurofeedback software that displays real-time visualization of brain activity.

The participants' self-regulated learning abilities were measured using the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich et al. (1991). The instrument has been adapted into an Indonesian version with good validity (r = 0.76) and reliability ($\alpha = 0.88$). The MSLQ consists of 81 items that measure the components of motivation and learning strategies on a 7-point Likert scale. In addition, the research team also developed a semi-structured interview protocol to explore participants' subjective experiences during dhikr practice and their perceptions of its impact on learning ability. This interview protocol has been validated by three competent experts in the fields of Islamic psychology, neuroscience, and education.

The research procedure is carried out in four main stages. The first stage is pre-test and orientation, where participants sign an informed consent, fill out a demographic data form, undergo baseline EEG measurements, fill out the MSLQ scale as a pre-test, and take part in an orientation session to introduce dhikr protocols and neurofeedback devices. The second stage is a dhikr intervention with neurofeedback that lasts for 4 weeks with a total of 12 sessions (3 sessions per week). Each session lasts 30 minutes consisting of preparation and installation of EEG electrodes, dhikr practice with guidance while receiving visual neurofeedback, and brief reflection on the experience of the session.

After the intervention is completed, the research enters the third stage, namely post-test and interview. At this stage, participants underwent post-intervention EEG measurements, refilled the MSLQ scale as a post-test, and 10 purposively selected participants followed a semi-structured interview. Then, one month after the intervention ended, a follow-up measurement was carried out in the fourth stage to assess the sustainability of the effects of the intervention on self-regulated learning ability.

The collected data is then analyzed using a comprehensive approach. For quantitative data, the research team conducted spectral power analysis on EEG data to identify changes in brain wave frequency, paired t-tests to compare pre-test and post-test MSLQ scores, Pearson correlation analysis to explore the relationship between changes in brain activity and changes in self-regulated learning scores, and covariance analysis (ANCOVA) to control for external variables such as previous experience in dhikr practice.

Meanwhile, qualitative data obtained from interviews were analyzed using a thematic analysis approach developed by Braun and Clarke (2006). This analysis process includes data familiarization, initial coding, theme search, theme review, theme definition and naming, and report writing. To help with this complex qualitative analysis process, the research team used NVivo 14 software.

As a final step, the research team integrated quantitative and qualitative data using the explanatory sequential design approach as recommended by Creswell and Plano Clark (2018). In this approach, quantitative results are used as the basis for qualitative exploration, and qualitative findings help to explain and enrich the interpretation of quantitative data, thus gaining a comprehensive and in-depth understanding of the phenomenon being studied.

3. FINDINGS AND DISCUSSION

Participant Characteristics

Of the 30 participants recruited, 28 (93.3%) completed the entire research series. Two participants withdrew for health reasons unrelated to the study. The demographic characteristics of the participants are presented in Table 1.

Table 1. Demographic Characteristics of Participants (n=28)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Man	14	50,0
	Woman	14	50,0
Age	18-20 years old	16	57,1
	21-25 years old	12	42,9
Faculty	Science and Technology	12	42,9
	Social Sciences and Humanities	10	35,7
	Medicine and Health	6	21,4
The Dhikr Experience	Minimum (<1 year)	18	64,3
	Moderate (1-3 years)	7	25,0
	Experienced (>3 years)	3	10,7

EEG Analysis Results

Analysis of EEG data showed significant changes in participants' brain activity patterns before, during, and after the dhikr intervention with neurofeedback. The results of spectral power analysis are presented in Table 2.

Table 2. Results of Brain Wave Spectral Power Analysis (mean ± SD)

Brain Waves	Pre-intervention	During dhikr	Post-intervention	Value *p*
Delta (0.5-4 Hz)	25.4 ± 6.2	22.8 ± 5.7	24.1 ± 5.9	0.182
Theta (4-8 Hz)	18.7 ± 4.3	24.6 ± 5.1*	21.2 ± 4.7*	0.008**
Alpha (8-13 Hz)	22.3 ± 5.6	32.7 ± 6.8*	27.4 ± 6.1*	<0.001**
Beta (13-30 Hz)	19.6 ± 4.8	15.2 ± 4.2*	18.4 ± 4.5	0.015*
Gamma (>30 Hz)	14.0 ± 3.9	9.7 ± 3.2*	12.3 ± 3.7*	0.006**

*Significantly different from pre-intervention ($p < 0.05$) **Significant at $p < 0.01$

These results showed a significant increase in alpha and theta waves during dhikr practice that continued until post-intervention measurements. Meanwhile, there was a significant decrease in beta and gamma waves during dhikr practice, which indicated a decrease in excessive mental activity and anxiety.

EEG topographic analysis (Figure 1) showed an increase in alpha activity mainly in the prefrontal, frontal, and parietal areas, which are related to executive function, attention regulation, and information processing. The theta increase is mainly seen in the central frontal and temporal areas, which are related to memory consolidation and information integration processes.

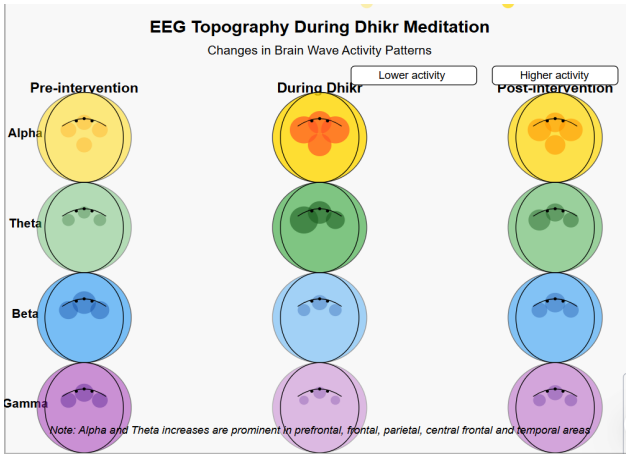

Figure 1. EEG Topography During Dhikr Meditation

Self-Regulated Learning Measurement Results

The results of the comparison of pre-test and post-test MSLQ scores are presented in Table 3.

Table 3. Comparison of Pre-test and Post-test MSLQ Scores (n=28)

MSLQ Components	Pre-test (red ± SD)	Post-test (red ± SD)	Mean Difference	Value *t*	Value *p*	Cohen's *d*
Motivation						
Intrinsic goal orientation	4.8 ± 0.9	5.4 ± 0.8	0.6	3.27	0.003**	0.70
Extrinsic goal orientation	5.2 ± 1.1	5.1 ± 1.0	-0.1	-0.42	0.676	0.09
Task value	5.1 ± 0.8	5.7 ± 0.7	0.6	3.48	0.002**	0.79
Learning confidence control	4.9 ± 0.9	5.6 ± 0.8	0.7	3.76	<0.001**	0.82
Self-efficacy	4.7 ± 1.0	5.5 ± 0.9	0.8	4.12	<0.001**	0.84
Test Effectiveness	4.3 ± 1.2	3.5 ± 1.0	-0.8	-3.94	<0.001**	0.72
Learning strategies						
Rehearsal	4.6 ± 0.8	4.8 ± 0.9	0.2	1.15	0.259	0.23
Elaboration	4.5 ± 0.7	5.2 ± 0.8	0.7	3.87	<0.001**	0.93
Organization	4.7 ± 0.9	5.3 ± 0.8	0.6	3.14	0.004**	0.70
Critical thinking	4.4 ± 1.0	5.0 ± 0.9	0.6	2.97	0.006**	0.63
Metacognitive	4.3 ± 0.8	5.1 ± 0.7	0.8	4.51	<0.001**	1.07
Time management	4.5 ± 1.1	5.2 ± 0.9	0.7	3.22	0.003**	0.69
Business regulation	4.4 ± 0.9	5.1 ± 0.8	0.7	3.64	0.001**	0.82
Peer learning	4.9 ± 1.0	5.2 ± 0.9	0.3	1.46	0.156	0.31
Search for help	4.7 ± 0.8	5.0 ± 0.9	0.3	1.57	0.128	0.35
Total MSLQ	**4.7 ± 0.6**	**5.2 ± 0.5**	**0.5**	**5.27**	**<0.001**	**0.89**

**Significant at p < 0.01

Results showed significant improvements in the total MSLQ score and the majority of subscales, especially in the metacognitive component that showed the largest effect size (d = 1.07). Insignificant improvements were found only in extrinsic goal orientation, rehearsals, peer learning, and help-seeking.

Correlation of Brain Activity with Self-Regulated Learning

Pearson's correlation analysis showed a significant relationship between changes in the spectral power of brain waves and changes in self-regulated learning scores (Table 4).

Table 4. Correlation of Changes in Brain Wave Activity with Changes in MSLQ Score

Brain Waves	Metacognitive (*r*)	Self-efficacy (*r*)	Business Regulation (*r*)	Time Management (*r*)	Total MSLQ (*r*)
Delta	0.15	0.12	0.09	0.11	0.14
Theta	0.56**	0.48**	0.44*	0.43*	0.52**
Alpha	0.62**	0.57**	0.53**	0.47**	0.59**
Beta	-0.31	-0.29	-0.35*	-0.38*	-0.33*
Gamma	-0.26	-0.19	-0.30	-0.25	-0.28

*p < 0.05, **p < 0.01

A strong positive correlation was found between increased alpha and theta waves with improved metacognitive abilities, self-efficacy, and total self-regulated learning scores. Meanwhile, there is a moderate negative correlation between the beta wave and business regulation and time management.

Results of Qualitative Analysis

The thematic analysis of the interview data identified five main themes that reflect the subjective experiences of the participants during the dhikr intervention with neurofeedback, as summarized in Table 5.

Table 5. Themes and Sub-themes of Thematic Analysis Results

Theme	Sub-theme	Sample Quotes
Increased Internal Awareness	-Awareness of physical sensations -Awareness of the mind -Awareness of emotions	"I became more aware of the thoughts that came and went... can observe without being carried away by the currents of thought." (P7)
Mental Calmness and Clarity	-Anxiety reduction -Clarity of thinking -Maintained focus	"My mind feels clearer and more organized, not as messy as it used to be." (P12)
Strengthening Spiritual Connections	-Feeling of closeness to Allah -Increased spiritual meaning -Transcendent experience	"I felt a peace and closeness to God that I had never felt before." (P3)
Transfer to Learning Activities	-Application of attention techniques -Intrinsic motivation increase Better self-regulation	"Now that I often use the same focus techniques while studying, it really helps with concentration." (P15)
Visualization of Neurofeedback as a Facilitator	-Awareness of brain activity -Motivation for improvisation -Objectification of internal experience	"Seeing the brain waves change during dhikr makes me better understand how my mind works." (P22)

These themes confirmed and enriched the quantitative findings, with participants consistently reporting improved ability to regulate attention and emotions, as well as transferring skills acquired during dhikr practice into the context of academic learning.

Follow-up Results

Follow-up measurements after 1 month showed that most of the improvement in self-regulated learning ability was maintained (Table 6).

Table 6. Comparison of MSLQ Scores Post-test and Follow-up (n=28)

Component	Post-test	Follow-up	Change (%)	Value *p*
Motivation	5.5 ± 0.7	5.3 ± 0.8	-3.6	0.136
Learning Strategies	5.1 ± 0.6	4.9 ± 0.7	-3.9	0.125
Total MSLQ	5.2 ± 0.5	5.0 ± 0.6	-3.8	0.104

Although there was a slight decrease in scores on follow-up measurements, the difference was not statistically significant, indicating the sustainability of the intervention effect.

Discussion

The results of this study show that the practice of dhikr integrated with neurofeedback can significantly affect brain activity and improve self-regulated learning abilities in Muslim students. These findings are in line with several neurobiological and psychological mechanisms that will be discussed below.

Changes in Brain Activity Patterns and Their Implications

Significant increases in alpha waves (8-13 Hz) during and after dhikr practice are consistent with previous research on meditation (Lomas et al., 2015; Lee et al., 2018). Alpha waves have been associated with a state of relaxed alertness, which facilitates an optimal balance between calmness and alertness (Klimesch, 2012). This condition is very conducive to the learning process because it creates a receptive mental state to new information while reducing internal and external distractions.

An increase in theta waves (4-8 Hz), especially in the frontal area, indicates the activation of prefrontal-hippocampal networks that play an important role in the consolidation of memory and the integration of new information with existing knowledge (Basar & Düzgün, 2016). These findings may explain significant improvements in elaboration and organizational abilities in the MSLQ learning strategy component, which involves the process of connecting new information with previous knowledge and organizing learning materials systematically.

A decrease in beta and gamma waves during dhikr reflects a reduction in excessive mental activity and anxiety (Hanslmayr et al., 2011). This is in line with a significant decline in test anxiety scores in MSLQ. Reduced anxiety allows for a more efficient allocation of cognitive resources to the learning process (Maloney et al., 2014).

From a neuroplasticity perspective, the practice of dhikr performed consistently for four weeks may have induced neuroplastic changes in the neural circuits involved in self-regulation. As suggested by Tang et al. (2021), repetitive mental exercise can strengthen neural connections and improve the efficiency of neural networks that support executive function, including the ability to plan, monitor, and evaluate cognitive activity—a core component of self-regulated learning.

Improvement of the Self-Regulated Learning Component

The improvement of metacognitive ability, showing the largest effect size (d = 1.07), is a finding that is highly relevant to the development of self-regulated learning. Metacognition, which involves awareness of and control over one's own cognitive processes, is the foundation for effective self-paced learning (Zimmerman & Schunk, 2019). The practice of dhikr may facilitate the development of metacognitive awareness through the strengthening of the ability to observe thoughts without excessive reactivity, similar to the mechanisms described in studies on mindfulness (Bernstein et al., 2019).

A significant increase in self-efficacy is also important because confidence in one's abilities is a strong predictor of academic performance (Honicke & Broadbent, 2016). Visualization of changes in brain activity in neurofeedback can provide objective evidence of participants' ability to modify their mental states, thus reinforcing the belief that they can control the learning process on their own.

Improvements in the components of intrinsic motivation, task scores, and learning belief controls indicate a shift in motivational orientation towards a more internal and autonomous direction. According to the theory of self-determination (Ryan & Deci, 2020), intrinsic motivation is essential for high-quality learning and long-term sustainability. In this context, the practice of dhikr can be seen as a means of cultivating internal circumstances conducive to intrinsically motivated learning.

Components that do not show significant improvement (extrinsic goal orientation, rehearsal, peer learning, and seeking help) tend to relate to external and mechanistic aspects of the learning process. This suggests that dhikr interventions with neurofeedback may have more of an internal and profound impact on self-regulation in learning than surface learning strategies.

Integration of Quantitative and Qualitative Findings

The themes that emerge from qualitative analysis provide a richer understanding of the psychological mechanisms behind quantitatively measurable change. The themes "Increased Internal Awareness" and "Mental Calmness and Clarity" correspond to changes in brain wave patterns (increase in alpha and theta, decrease in beta) and improvement in metacognitive abilities. Increased awareness of thoughts and emotions is a prerequisite for effective self-regulation in the context of learning (Pintrich, 2004).

The theme "Transfer to Learning Activities" is significant because it shows that skills developed during dhikr practice can be transferred to the academic domain. This is consistent with the model of learning transfer in educational psychology that emphasizes the importance of generalizing skills from one context to another (Barnett & Ceci, 2002).

The theme "Strengthening Spiritual Connections" adds a dimension that is rarely discussed in the mainstream literature on self-regulated learning, but is very relevant to the perspective of Islamic holistic education. As emphasized by Al-Attas (2019), true Islamic education aims to develop intellectual and spiritual potential in an integrated manner. These findings highlight how the spiritual dimension can contribute to the development of cognitive abilities.

The theme "Visualization of Neurofeedback as a Facilitator" reveals the unique value of the neurofeedback component in the intervention. The ability to see changes in brain activity in real-time appears to provide a "concrete grip" for participants to understand and modify their mental state—a form of externalization of internal processes that is difficult to observe. This supports the argument for the "near transfer" between self-regulation during dhikr and self-regulation in learning activities (Barnett & Ceci, 2002).

Theoretical and Practical Implications

Theoretically, this research bridges the gap between Islamic spiritual neuroscience and contemporary educational psychology, offering an integration model that enriches both fields. The findings of this study support a self-regulated learning model that emphasizes dynamic interactions between cognitive, motivational, and affective aspects (Pintrich, 2004; Zimmerman & Schunk, 2019), while adding a spiritual dimension that is rarely explored in mainstream literature.

Practically, the results of this study show the potential for the development of dhikr-based intervention protocols with neurofeedback to improve self-regulated learning skills in Islamic educational institutions. This kind of protocol can be integrated into the curriculum as an innovative approach to developing 21st-century learning skills while strengthening the religious identity of Muslim students.

Limitations and Recommendations for Further Research

This research has several limitations that need to be considered. First, the relatively small sample size limits the generalizability of the findings. Second, the absence of a control group limited the ability to isolate the specific effects of dhikr interventions with neurofeedback from non-specific effects such

as expectation and extra attention. Third, a relatively short follow-up period (1 month) could not ensure the sustainability of the long-term effect.

For further research, it is recommended to: (1) conduct studies with a randomized controlled trial design and larger sample sizes; (2) comparing the effectiveness of dhikr with and without neurofeedback to identify the added value of the neurofeedback component; (3) conduct longitudinal studies with longer follow-up periods to assess the sustainability of effects; (4) explore the effectiveness of protocols for populations with different characteristics (e.g., age, cultural background); and (5) delve deeper into the neurobiological mechanisms underlying the effects of dhikr on cognitive function using more advanced brain imaging technologies such as fMRI.

4. CONCLUSION

This study demonstrates that the integration of dhikr practice with neurofeedback technology can effectively improve self-regulated learning skills in Muslim students. Neurophysiological findings show changes in brain activity patterns conducive to learning, with increased alpha and theta waves positively correlated with improved metacognitive abilities, self-efficacy, and self-regulation. The transfer of skills from the spiritual context to the academic domain was confirmed through qualitative data, demonstrating the practical value of these interventions.

Theoretically, the research bridges the gap between neuroscience, educational psychology, and Islamic spirituality, offering a comprehensive framework for understanding the relationship between spiritual practice and cognitive development. This interdisciplinary approach enriches the conception of self-regulated learning by adding a spiritual dimension that is rarely explored in mainstream literature.

Practically, the research findings support the development of dhikr-based educational protocols and neurofeedback that can be implemented in Islamic educational institutions to develop 21st century learning skills while maintaining spiritual authenticity. The sustainability of positive effects on follow-up measurements indicates the potential for interventions to produce long-term change.

Despite its limitations in sample size and quasi-experimental design, this study lays the groundwork for further exploration of the synergies between Islamic spiritual practices, neurofeedback technology, and cognitive ability development. Future research is recommended to use RCT designs with larger samples, compare the effectiveness of dhikr with/without neurofeedback, conduct longitudinal studies, and delve deeper into the underlying neurobiological mechanisms. Overall, "Islamic neurofeedback" offers a holistic approach to education that integrates intellectual and spiritual development, in line with the vision of Islamic education that blends knowledge and charity.

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