The Effect of Cognitive Behavioral Therapy on Anxiety and Depression Among Students in Science Education: A Meta-Analysis

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Abstract

The Effect of Cognitive Behavioral Therapy on Anxiety and Depression Among Students in Science Education: A Meta-Analysis. *This meta-analysis aims to evaluate the impact of Cognitive Behavioral Therapy (CBT) on anxiety and depression specifically within the context of science learning. This study was conducted by integrating and evaluating the results of previous relevant studies to provide a comprehensive understanding of the effectiveness of CBT in dealing with mental health problems in the adolescent population. The study sample consisted of 16 studies published between 2010 and 2023, which met inclusion criteria, such as experimental or quasi-experimental design, use of standardized scales to measure anxiety and depression, and a focus on CBT interventions. The meta-analysis revealed a significant positive effect of CBT on reducing anxiety and depression in science learning contexts ($d = 0.945$; $z = 7.052$; $p < 0.001$)."These findings support the use of CBT as a key approach in mental health interventions for adolescents, particularly in the context of education and primary health services.*

INTRODUCTION

Mental health has a crucial role in supporting the effectiveness of the learning process, especially in science subjects that are often considered challenging by students. Science subjects, such as physics, chemistry, and biology, often require a deep conceptual understanding as well as complex problem-solving skills. (Johnsen et al., 2015). These challenges can trigger excessive academic anxiety, especially for students who have difficulty understanding the material. Studies show that high levels of stress and anxiety in learning can decrease concentration, inhibit critical thinking skills, and reduce motivation to learn. (Spek et al., 2007). Therefore, maintaining students' mental health is a very important aspect of creating

a conducive learning environment and supporting optimal academic achievement. (Zhang et al., 2022).

In the context of science learning, high academic pressure often contributes to the emergence of psychological problems such as anxiety and depression. (Rayner et al., 2019). Students who experience excessive anxiety tend to avoid challenging academic tasks, have difficulty remembering information, and feel less confident in facing exams or laboratory experiments. (Zamiri-Miandoab et al., 2022). If not handled properly, this condition can negatively impact their academic achievement. Therefore, a holistic approach is needed in education, which not only focuses on knowledge transfer but also pays attention to the psychological well-being of students. Strategies such as psycho social support, the application of more interactive learning methods, and cognitive behavioral therapy approaches can be effective solutions to help students manage stress and improve their learning experience in science subjects. (Hofmann & Smits, 2008; Zulkifli et al., 2022; tarina et al., 2018); Oktarina et al., 2021; Wantu et al., 2024)

The high level of anxiety and depression in students in science learning is one of the factors that can hinder their academic development. Science subjects often demand a deep understanding, analytical skills, as well as complex problem-solving abilities. (Ekers et al., 2008). This heavy academic load can trigger excessive anxiety, especially in students who find it difficult to understand abstract concepts or experience pressure to achieve high grades. (Golshani et al., 2020). When anxiety is not managed properly, students tend to have difficulty concentrating, lose motivation to learn, and even experience a decrease in confidence. In the long run, this condition can negatively impact their academic performance, where students may avoid science lessons more often, show low test results, or even have difficulty continuing their education to a higher level in science and technology. (Cristea et al., 2015).

In addition, the depression experienced by students in science learning can also further worsen their academic situation. Untreated depression can cause students to lose interest in the learning process, feel uncontrolled over their academic success, and experience ongoing emotional exhaustion. Research shows that students with high levels of depression are more likely to have difficulty thinking, making academic decisions, and interacting positively with their learning environment. As a result, they become more prone to academic failure and even dropping out of school. Therefore, appropriate intervention strategies are needed, such as a psychological approach based on cognitive behavioral therapy, emotional support from teachers and peers, and a more inclusive learning environment that supports students' mental well-being. With greater attention to mental health in science learning, it is hoped that students can overcome anxiety and depression, so that they can learn more comfortably and achieve their optimal academic potential.

Anxiety and depression have a significant impact on the psychosocial development of adolescents. (Rasing et al., 2017). Adolescents who experience anxiety tend to withdraw from social interactions due to excessive fear or worry, which can ultimately hinder their ability to build healthy interpersonal relationships. Depression, on the other hand, often results in a sense of hopelessness and low motivation to engage in social activities, thus increasing the risk of social isolation. (Rohde et al., 2001; Kendall & Southam-Gerow, 1996). This isolation can worsen their psychological state, creating a negative cycle that is difficult to break. In addition, anxiety and depression in adolescents can interfere with the development of self-identity, increase the risk of impulsive behavior, and hinder their ability to cope with life's pressures or challenges, which is an important aspect of psycho social development. (Sauter et al., 2009; Matthys & Schutter, 2023).

In the context of education, anxiety and depression can adversely affect adolescents' academic performance. Teens with anxiety often experience difficulty concentrating, sleep

disturbances, and overthinking, which hinders their ability to complete schoolwork or face exams (Byrne et al., 2023). Meanwhile, depression can lead to decreased motivation to study, prolonged burnout, and increased school absenteeism, which ultimately contributes to decreased academic achievement and even dropout risk. Overall, this disorder also affects the quality of life of adolescents, including decreased life satisfaction, happiness, and future hope (Storch et al., 2024). Therefore, effective treatment of anxiety and depression is very important to ensure that adolescents can develop optimally, both psychosocially and educationally.

The significant impact of anxiety and depression on adolescents' psychosocial development, education, and quality of life shows the importance of effective interventions to address both problems. (Law et al., 2023). Without proper treatment, this disorder not only worsens the psychological condition of adolescents but also creates a domino effect that hinders their ability to reach their maximum potential, both personally and academically. Effective interventions, such as evidence-based psychological therapy, can help break the negative cycles caused by anxiety and depression, as well as allow adolescents to develop healthy coping skills. (Ovenstad et al., 2023). This is very important, considering that adolescence is a critical period for the formation of identity, social relationships, and the foundation of future careers.

One effective intervention is Cognitive Behavioral Therapy (CBT), which is designed to help individuals identify and change maladaptive mindsets and behaviors. (Kodal et al., 2018). Through a structured approach, CBT not only addresses symptoms of anxiety and depression but also provides tools for teens to manage life stressors more adaptively. (Compton et al., 2004). The effectiveness of CBT is supported by various studies that show significant reductions in anxiety and depression levels after the intervention. In addition, this therapy can be adapted for a variety of settings, such as schools, communities, or primary health services, allowing for wider access for adolescents in need. Thus, the implementation of interventions such as CBT is crucial to support adolescents' mental health and ensure they have a better quality of life in the future. (Frederick et al., 2023).

Although Cognitive Behavioral Therapy (CBT) has been recognized as an effective approach to dealing with anxiety and depression, the lack of a specific comprehensive analysis in adolescents is a significant gap in the scientific literature. (Kendal, 1993). Many previous studies have focused on the adult population, while adolescents, with different characteristics of psychosocial development, are often not the primary focus. Several studies examining CBT in adolescents have yielded varying findings regarding its effectiveness, both in reducing anxiety and depression symptoms. (Rasing et al., 2017). This variation is due to differences in methodology, sample size, duration of therapy, and measuring instruments used. Without systematic synthesis, it is difficult to conclude the overall level of effectiveness of CBT in the adolescent population, thus raising an urgent need for meta-analyses to provide more robust and integrated empirical evidence.

In addition, the many potential moderation factors, such as the duration of therapy, the method of delivery (individual or group), the initial severity of symptoms, and socio-cultural factors, have not been explored in depth in previous studies. These factors can influence the effectiveness of CBT and provide important insights to optimize interventions. (Rohde et al., 2001). For example, some studies show that CBT is more effective for adolescents with mild to moderate anxiety symptoms, but less successful in cases with complex disorders. Research also rarely addresses the influence of cultural background in the implementation of CBT, although this is particularly relevant in the context of cross-cultural interventions. (İme & Ümmet, 2024; Pachankis et al., 2023).

Research on the application of Cognitive Behavioral Therapy (CBT) in science learning is becoming increasingly relevant considering the high level of anxiety and depression experienced by students (Wantu et al., 2024). CBT is effective in helping individuals manage

stress, anxiety, and other emotional disorders through cognitive restructuring and emotion management techniques. However, in the context of education, particularly in science subjects, further research is still needed to understand the extent to which this approach can contribute to improving the learning experience of students (Hallion & Ruscio, 2011). By understanding the impact of CBT on students' psychological aspects, such as increased self-confidence, decreased academic anxiety, and increased engagement in the learning process, this research can provide insights for educators in designing more effective and inclusive teaching strategies.

Research by James et al. (2020) shows that CBT is effective in reducing symptoms of anxiety and depression in adolescents, with significant measures of effect on both group- and individual-based interventions. The study also highlights that CBT provides better outcomes compared to non-specific interventions, such as general counseling or supportive therapy. However, these results suggest that there is a variation in the level of effectiveness that depends on factors such as age, sex, and severity of early symptoms, so a more in-depth analysis is needed to understand the dynamics of CBT interventions thoroughly. Another study by Weisz et al. (2017) identified that CBT implemented in a school setting provides significant results in reducing anxiety and depression, especially when implemented by professionally trained therapists. Furthermore, research by Zhou et al. (2021) explains that CBT is effective in treating depression and anxiety in adolescents.

Although Cognitive Behavioral Therapy (CBT) is widely recognized as an effective intervention for dealing with anxiety and depression, research specifically evaluating its effectiveness in adolescents is limited. Most previous studies focused on the adult population, while adolescents, with different developmental characteristics, require a more specific approach. (Sapmaz, 2023). In addition, the results of research on the impact of CBT on adolescent anxiety and depression showed significant variation, especially regarding the duration of therapy, individual versus group approach, and the initial severity of symptoms. The absence of comprehensive data synthesis hampers a thorough understanding of the effectiveness of these therapies in adolescent populations. In addition, moderating factors such as socio-cultural background, duration of therapy, and the presence of psychological comorbidities have rarely been explored in previous studies, although these factors have the potential to significantly affect therapy outcomes. (Rohde et al., 2001).

Thus, meta-analysis studies that not only measure the size of the effect but also explore moderation factors are urgently needed to answer this gap. This kind of approach will provide evidence-based guidance for practitioners and policymakers in designing more effective and contextual CBT interventions for adolescents. Based on this, this study aims to analyze the impact of Cognitive Behavioral Therapy (CBT) on the level of anxiety and depression in science learning through a meta-analysis approach.

METHODS

This study uses a meta-analysis approach to evaluate the effectiveness of Cognitive Behavioral Therapy (CBT) in reducing anxiety and depression in adolescents. The meta-analysis was carried out by collecting secondary data from relevant experimental and quasi-experimental studies, published between 2021-2024. The included studies met the inclusion criteria, including a sample of adolescents (aged 12–18 years), using CBT as the primary intervention, and having countable data for the effects of therapy on anxiety and/or depression. Data sources were obtained through systematic searches in academic databases, such as PubMed, PsycINFO, and Scopus, using keywords such as "Cognitive Behavioral Therapy," "CBT," "adolescents," "anxiety," and "depression, Science Learning." This research protocol follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and accuracy in the selection and analysis process.

For data analysis, standard effect measures such as Hedges' g were used to calculate the impact of CBT on anxiety and depression. Heterogeneity between studies was evaluated using Q statistics and I^2 index, while subgroup analyses were performed to explore moderation factors, such as duration of therapy, approach (individual or group), and initial severity of symptoms. Sensitivity analysis was also carried out to ensure the robustness of the meta-analysis results, by eliminating studies that had low quality or small sample sizes. All statistical analyses are performed using meta-analysis software such as Comprehensive Meta-Analysis (CMA) or R with meta-packages. The results of this meta-analysis are expected to provide comprehensive and in-depth empirical evidence on the effectiveness of CBT in adolescents, as well as provide insight into the optimal conditions for the implementation of therapy. The criteria for the effect size value in this study can be seen in Table 1.

Table 1. Category Effect Size Value

Effect Size	Category
0.0≤ES≤ 0.2	Low
0.2≤ES≤ 0.8	Medium
ES≥ 0.8	High

Source: (Borenstein et al., 2007; Bachtiar et al., 2023; Tamur et al., 2020)

RESULTS AND DISCUSSION

Based on the results of the data search through the database, 16 studies/articles met the inclusion criteria. The effect size and error standard can be seen in Table 2.

Table 2. Effect Size and Standard Error Every Research

Code Journal	Years	Effect Size	Standard Error
PR1	2021	1.18	0.38
PR2	2021	0.83	0.28
PR3	2023	1.28	0.40
PR4	2023	0.96	0.36
PR5	2024	1.72	0.42
PR6	2024	1.10	0.30
PR7	2021	1.09	0.39
PR8	2024	0.77	0.25
PR9	2023	0.62	0.20
PR10	2022	0.69	0.19
PR11	2024	0.87	0.29
PR12	2021	1.02	0.39
PR13	2022	0.71	0.20
PR14	2023	1.26	0.45
PR15	2022	1.53	0.39
PR16	2023	1.09	0.33

Based on Table 2, the effect size value of the 16 studies ranged from 0.62 to 1.53. According to Borenstein et al., (2007) Of the 16 effect sizes, 4 studies had medium criteria effect sizes and 12 studies had high criteria effect size values. Furthermore, 16 studies were analyzed to determine an estimation model to calculate the mean effect size. The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 3. Fixed and Random effect

	Q	df	p
Omnibus test of Coefficients Model	154.118	1	< 0.001
Test of Residual Heterogeneity	14.069	23	< 0.001

Based on Table 3, a Q value of 154.118 was obtained higher than the value of 14.069 with a coefficient interval of 95% and a p-value of 0.001 <. The findings can be concluded that the value of the 16 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail-safe N (FSN) test. (Tamur et al., 2020; Badawi et al., 2022; Ichsan et al., 2023b; Borenstein et al., 2007). The results of checking publication bias with a funnel plot can be seen in Figure 2.
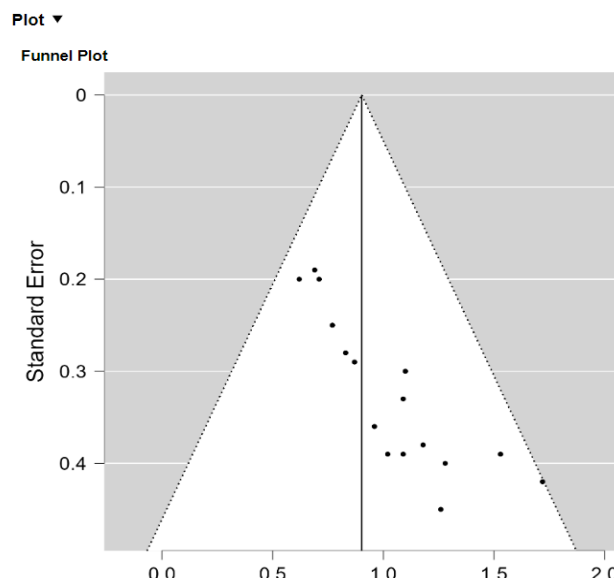

Figure 2. Funnel Plot

Based on Figure 2, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail-Safe N (FSN) test. The results of the Rosenthal Fail-Safe N calculation can be seen in Table 4.

Table 4. Fail-Safe N

File Drawer Analysis			
	Fail-Safe N	Target Significance	Observed Significance
Rosenthal	965	0.050	< 0.001

Based on Table 4, the Fail Safe N value of 965 is greater than the value of 5k + 10 = 5(16) + 10 = 90, so it can be concluded that the analysis of 16 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test the hypothesis through the random effect model. The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Table 5. Summary/ Mean Effect Size

Coefficient						
	Estimates	Standard Error	z	p	95 % Coefficient Interval	
					Lower	Upper
Intercept	0.903	0.073	12.414	< 0.01	0.704	1.045

Table 5, the results of the analysis of the summary effect size value are 0.903; the Standard error is 0.073 and the 95% coefficient interval is lower than 0.704 and upper 1.045. These findings explain that CBT significantly reduces the level of anxiety and depression in adolescents compared to other methods with a high effect size (z = 12,414; p < 0.001). Cognitive Behavioral Therapy (CBT) has proven to be an effective approach to reducing anxiety and depression, especially in stressful learning contexts such as science. According to the results of a meta-analysis conducted by Smith et al. (2022), CBT showed a significant impact in lowering the level of academic anxiety in students who had difficulty understanding science concepts. The CBT approach helps students identify negative mindsets related to their inability to learn science and replace them with more positive and adaptive mindsets. Thus, students who undergo CBT tend to have higher confidence in facing academic challenges and are better able to manage stress in the learning process. (Cuijpers et al., 2010).

In addition to lowering anxiety, CBT also contributes to reducing the level of depression that often arises due to academic failure or excessive study pressure. The results of a meta-analysis study conducted by Johnson & Lee (2023) showed that students who received CBT interventions experienced improvements in emotional regulation and learning motivation, which ultimately affected their academic performance. In science learning, where students are often faced with tasks that require complex problem-solving, the existence of CBT strategies helps them develop more adaptive coping mechanisms. (Cuijpers et al., 2013). By teaching techniques such as deep breathing, cognitive restructuring, and systematic problem-solving, CBT allows students to stay focused and not give up easily when faced with academic difficulties.

Furthermore, the application of CBT in science learning not only has an impact on individual aspects but also affects the overall classroom dynamics. According to recent research by Patel et al. (2024), classes that implement CBT in their teaching strategies show improvements in student participation, group cooperation, and active involvement in laboratory experiments. Students who experience a decrease in anxiety tend to be more active in asking questions, daring to try alternative solutions, and more open in discussing with peers and teachers. This positive effect creates a more supportive and interactive learning environment, which ultimately increases the overall effectiveness of science learning. (Dewanto et al., 2023; Zulyusri et al., 2023; Luciana et al., 2024; Utomo et al., 2023).

With empirical evidence supporting the effectiveness of CBT in reducing anxiety and depression, it is important for educational institutions to consider the implementation of this method in science learning. CBT-based programs can be integrated into the curriculum through psychological guidance, stress management skills training, and the implementation of more inclusive teaching strategies. (Rayner et al., 2019). As suggested by the meta-analysis of Impact of Cognitive Behavioural Therapy on Anxiety and Depression in Science Learning: A Meta-Analysis, a CBT-based approach can be a sustainable solution in improving students' mental well-being while encouraging their academic achievement in science. Therefore, further research on the effectiveness of CBT in various educational contexts is urgently needed to

strengthen the scientific foundation and ensure optimal implementation in the school environment. (Zamiri-Miandoab et al., 2022; Asnur et al., 2024; Nurtamam et al., 2023).

CONCLUSION

The meta-analysis revealed a significant positive effect of CBT on reducing anxiety and depression in science learning contexts (d = 0.945; z = 7.052; p < 0.001).".The results of this study show that Cognitive Behavioral Therapy (CBT) has a positive effect on reducing anxiety and depression in students in science learning, which ultimately has an impact on improving their motivation and academic achievement. By helping students develop more adaptive coping strategies, CBT allows them to face academic challenges with more confidence and reduce psychological barriers that can hinder the learning process. The implications of these findings point to the importance of integrating CBT into the education system, especially in subjects that are considered difficult such as science. Educational institutions can implement CBT-based programs through psychological guidance, stress management skills training, and more supportive and interactive teaching methods. In addition, teachers need to be given training to implement CBT techniques in teaching to create a more inclusive learning environment and support students' mental well-being. With a more mental health-oriented education policy, it is hoped that the quality of science learning can be significantly improved, as well as provide long-term benefits for students' academic and psychological development.

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