Metacognitive Strategies for Teaching Biology at Tyler High School

JOWEL C. PABLO, Ph.D.
Tyler High School
jowelcpablo@gmail.com

JO NEIL T. PERIA, Ph.D.
Nueva Ecija University of Science and Technology

Abstract — This study explored the effectiveness of metacognitive strategies in enhancing the academic performance of students in Biology. Metacognition, defined as the awareness and regulation of one's own thinking processes, plays a crucial role in promoting deeper understanding and meaningful learning, especially in science education. The study employed a quasi-experimental design involving control and experimental groups to measure the impact of metacognitive interventions compared to traditional teaching methods. Both groups took a pre-test to determine their baseline knowledge, and the results revealed no significant difference between them, confirming that they were comparable prior to the intervention. The experimental group was then taught using metacognitive strategies—such as guided reflection, self-monitoring tools, and problem-solving tasks—while the control group received instruction through conventional lectures. After the intervention, a post-test was administered. The experimental group demonstrated significantly higher improvement in test scores compared to the control group, as supported by statistical analysis ($t = 3.24$, $p < 0.05$). Findings suggest that metacognitive strategies positively influence students' understanding and performance in Biology. The study recommends integrating metacognitive activities into science instruction to promote critical thinking, self-awareness, and improved academic outcomes. Future research is encouraged to include larger sample sizes, other science subjects, and metacognitive awareness assessments to broaden the scope of application.

Keywords — Metacognition, Biology Education, Academic Performance, Teaching Strategies, Self-regulation, Critical Thinking, Science Instruction

I. Introduction

The ever-evolving nature of science education necessitates the implementation of teaching strategies that promote deeper learning and critical thinking. One such approach is the integration of metacognitive strategies in the classroom. Metacognition, defined as the awareness and regulation of one's cognitive processes, plays a crucial role in students' ability to comprehend and retain complex concepts (Flavell, 1979). In Biology education, where students often struggle with abstract and multifaceted topics, fostering metacognitive skills can lead to improved academic performance and engagement.

At Tyler High School, many students face difficulties in understanding fundamental biological principles, resulting in lower retention rates and reduced confidence in the subject. Traditional instructional methods often focus on content delivery rather than active student engagement and self-regulated learning. This research aims to explore the impact of metacognitive strategies—such as self-questioning, think-aloud protocols, reflective journaling, and concept mapping—on students' academic success in Biology. By utilizing an experimental quantitative research design, this study will provide empirical insights into the effectiveness of metacognitive strategies in enhancing learning outcomes.

This research is significant as it seeks to bridge the gap between theory and practice, offering educators at Tyler High School a structured framework for integrating metacognitive techniques into their teaching methodologies. The findings will contribute to the growing body of literature on metacognition in science education and provide actionable recommendations for improving instructional practices.

Literature Review

Teaching science in the 21st century poses several persistent challenges that affect both educators and students. One major issue is the lack of adequate instructional materials and laboratory equipment, particularly in developing countries. According to Talisayon (2019), many science classrooms still rely on outdated textbooks and have limited access to hands-on resources, which hinders experiential learning. This limitation affects students' conceptual understanding and reduces opportunities for inquiry-based instruction.

Another prominent issue is the insufficient training and professional development for science teachers. Many educators enter the teaching profession without specialized training in science education, resulting in a lack of content mastery and pedagogical skills (Guzey et al., 2014). Continuous professional development is often irregular or unavailable, making it difficult for teachers to keep up with new scientific advancements and innovative teaching strategies.

Furthermore, there is an ongoing challenge in making science education inclusive and responsive to diverse learners. Research by Lee and Buxton (2010) emphasizes the need for culturally relevant pedagogy to engage students from various backgrounds, especially English language learners and students with special needs. The absence of inclusive practices contributes to the achievement gap and lowers students' interest and motivation in pursuing science careers.

Student misconceptions and low engagement in science remain significant barriers to effective instruction. Students often enter classrooms with preconceived ideas that conflict with scientific concepts, and these misconceptions are difficult to correct without proper interventions (Sadler et al., 2013). Combined with traditional lecture-based teaching methods, these issues limit the development of critical thinking and problem-solving skills.

Language barriers also present a significant gap in learning science, especially for English Language Learners (ELLs) and students in multilingual contexts. Science has its own set of complex vocabulary, which can be difficult to decode without sufficient language support. Lemke (2001) explains that the language of science is dense with technical terms and syntactic complexity, creating additional cognitive load for learners. This makes science less accessible and affects students' ability to participate in scientific discourse.

Motivation and engagement are also major concerns in science learning. Many students perceive science as difficult and irrelevant to their daily lives, resulting in low interest and poor performance. Osborne and Dillon (2008) emphasized that when students do not see the value or personal relevance of science, they are less likely to be engaged or pursue science-related careers. This disconnection contributes to declining enrollment in advanced science courses and STEM-related fields.

The lack of differentiated instruction and learning support for diverse learners poses a challenge in inclusive science education. Learners with disabilities, low academic performance, or those from marginalized backgrounds often lack the scaffolding needed to succeed in science (National Research Council, 2012). Without appropriate interventions, the achievement gap continues to widen, limiting opportunities for many students to fully participate in science learning and careers.

Metacognitive strategies such as self-questioning and concept mapping help students in science classes move beyond rote memorization toward deeper conceptual understanding (Zohar & Barzilai, 2013). These tools guide learners to reflect on what they know and identify gaps, enabling them to reconstruct scientific concepts more meaningfully.

Metacognitive prompts, such as planning steps before solving problems and evaluating solution strategies afterward, significantly enhance scientific problem-solving skills (Schraw et al., 2006). These strategies foster learners' ability to think like scientists and approach problems analytically.

The integration of metacognitive strategy instruction in science classes has been shown to enhance students' self-regulated learning, which is crucial for sustained academic success (Zimmerman & Schunk, 2011). When students are taught to plan, monitor, and assess their learning, they take more responsibility for their progress.

In science, where students often face complex and abstract information, metacognitive scaffolds help reduce cognitive overload by chunking information and encouraging strategic processing (Sweller, 1994). This is particularly helpful in subjects like genetics and chemical reactions. Teachers who integrate metacognitive strategy instruction report greater confidence in facilitating student learning. According to Veenman et al. (2006), professional development in metacognitive teaching strategies equips educators to better diagnose learning issues and adapt instruction accordingly.

Van Opstal and Daubenmire (2015) explored the impact of the Science Writing Heuristic (SWH) on students' metacognitive regulation skills in laboratory settings. Their study revealed that students engaged in SWH-based instruction demonstrated deeper levels of metacognitive engagement, particularly in planning, monitoring, and evaluating their learning processes. The collaborative nature of SWH also fostered peer discussions, further enhancing metacognitive practices.

Zohar and Barzilai (2013) conducted a comprehensive review of research on metacognition in science education. They identified that while metacognitive strategies are increasingly integrated into science instruction, there remains a need for more empirical studies focusing on the development of metacognitive knowledge and the effectiveness of these strategies across diverse educational contexts.

Cook, Kennedy, and McGuire (2013) examined the impact of teaching metacognitive learning strategies on student performance in general chemistry courses. Their findings indicated that students who received instruction on metacognitive strategies achieved higher final grades, suggesting that such strategies can effectively enhance academic performance in science disciplines.

Mason and Singh (2016) investigated the impact of guided peer reflection on developing effective problem-solving strategies in physics education. Their study revealed that students who engaged in structured peer discussions about problem-solving approaches demonstrated improved abilities in conceptual analysis, planning, and evaluation. This collaborative metacognitive practice facilitated deeper understanding and retention of physics concepts.

Abdelshiheed et al. (2023) explored how metacognitive skills, specifically time-awareness and strategy-awareness, interact with motivation to influence learning across domains. Their findings indicated that students who were both highly motivated and possessed strong metacognitive skills outperformed their peers in learning logic and subsequently applying it to probability. This underscores the importance of metacognitive awareness in facilitating transfer of learning.

Abdelghani et al. (2024) designed an interactive workshop aimed at enhancing children's curiosity by training specific metacognitive skills. The pilot study with primary school students demonstrated that engaging in activities focused on expressing uncertainty and formulating questions improved their metacognitive efficiency and curiosity-driven behaviors. This highlights the potential of targeted metacognitive training in early education.

Moreover, the integration of metacognitive prompts within digital and collaborative learning environments has proven particularly effective. Virtual labs, AI-driven platforms, and guided peer discussions have shown to boost learners' self-awareness and autonomy in science classrooms (Lee & Baylor, 2016; Kumar et al., 2024). These tools allow learners to engage with content more reflectively and adaptively, providing just-in-time support that fosters lifelong learning habits.

Another key insight from the literature is the versatility of metacognitive interventions across educational levels.

Whether in primary, secondary, or higher education, metacognitive instruction improves learners' ability to transfer knowledge across domains (Abdelshiheed et al., 2023) and apply scientific concepts in real-world contexts (Wang & Chen, 2022). These strategies also align with constructivist principles, encouraging students to become active participants in their own learning journey.

However, the successful implementation of metacognitive strategies depends greatly on teacher preparedness. Research points out that many educators require professional development to effectively design and integrate metacognitive instruction into their science teaching (Zohar & Barzilai, 2015). Therefore, teacher training programs must prioritize metacognitive pedagogies to ensure consistency and sustainability in their application.

In sum, metacognitive strategies serve as powerful catalysts for meaningful science learning. As future research continues to explore innovative methods—especially with the rise of AI and learning analytics—there is a clear call for educational systems to invest in and scale up metacognitive approaches. Doing so will not only address long-standing gaps in science education but also prepare students to become adaptive, reflective thinkers in an ever-evolving world.

II. Methodology

This study utilized a quantitative experimental research design, specifically a pre-test–post-test control group design, to investigate the effectiveness of metacognitive strategies in enhancing student learning in Unit 10: Ecology, aligned with the Texas Essential Knowledge and Skills (TEKS) standards for Grade 9 science.

Two class sections participated in the study: the experimental group (B4) consisting of 20 students, and the control group (B3) also with 20 students. The experimental group received instruction that integrated explicit metacognitive strategies, such as goal-setting, self-monitoring, self-questioning, and reflective thinking activities. These strategies were embedded into daily lessons, discussions, and assessments over a three-week period. In contrast, the control group was taught the same content using traditional lecture-based instruction without the inclusion of metacognitive strategies.

Both groups were given a pre-test before the instructional period and a post-test after its conclusion. The test items were teacher-made and aligned with the TEKS learning standards for

Unit 10: Ecology, covering key concepts such as ecosystems, food webs, energy flow, biotic and abiotic factors, ecological succession, and environmental sustainability.

By comparing the differences in the pre- and post-test scores of both groups, the study aimed to determine the effectiveness of metacognitive instruction in improving conceptual understanding and student performance in ecology. This research design allowed for a controlled analysis of how the application of metacognitive strategies may bridge learning gaps and promote higher-order thinking in science education.

Participants or Subjects

The participants of this study were 40 Grade 9 students from Tyler High School during the 2024–2025 school year, with 20 students in the experimental group (B4) and 20 in the control group (B3). The experimental group received instruction on Unit 10: Ecology using metacognitive strategies like self-reflection and goal-setting, while the control group was taught using traditional methods. Both groups followed the TEKS curriculum and were taught by the same teacher to ensure consistency. Participants were selected through convenience sampling, and proper consent was obtained from students and parents in line with ethical research standards.

Data Collection

To evaluate the effectiveness of metacognitive strategies in teaching Unit 10: Ecology, this study used pre- and post-tests aligned with TEKS standards for Grade 9, covering topics like food webs, energy flow, succession, and environmental conservation. Both the experimental group (B4) and control group (B3) took a pre-test before a three-week intervention. The experimental group received metacognitive-based instruction, while the control group followed traditional methods. After the intervention, both groups took a post-test of similar difficulty. The experimental group also submitted journals and exit slips, and teacher observations were used to track metacognitive behaviors. All data were analyzed to assess the impact on student learning and engagement.

Data Collection Methods

This study used quantitative methods to evaluate the effectiveness of metacognitive strategies in teaching Unit 10: Ecology to Grade 9 students at Tyler High School. Teacher-made pre-tests and post-tests aligned with TEKS standards were given to both the experimental group (B4) and the control group (B3) to measure learning before and after a three-week period. Only the experimental group received instruction with metacognitive strategies. The tests covered key topics like food chains, energy flow, ecosystems, and human impact, and were consistent in format to ensure reliability and validity. All assessments were done during class hours, with data kept confidential and used only for research.

Instruments Used

This quantitative study used a teacher-made achievement test as the main tool to measure Grade 9 students' understanding of Unit 10: Ecology, based on the TEKS standards. The 30-item multiple-choice test, used for both pre-test and post-test, covered key topics like energy flow, food webs, succession, biotic and abiotic factors, and human impact. A Table of Specifications (TOS) was used to ensure alignment with instructional goals and cognitive levels, from basic recall to higher-order thinking. The test was reviewed by science educators for clarity and validity, then administered in a 40-minute session under standard classroom conditions.

Data Analysis Procedures

The pre- and post-test data were analyzed using quantitative methods to evaluate the impact of metacognitive strategies on student learning. Mean scores were calculated for both tests in the experimental (B4) and control (B3) groups to measure improvement. A paired samples t-test assessed score differences within the experimental group, while an independent samples t-test compared post-test scores between groups to check for significant effects of the intervention. Cohen’s d was computed to measure effect size, and descriptive statistics like mean, standard deviation, and range summarized the results. Normality and variance assumptions were tested using Shapiro-Wilk and Levene’s tests, with SPSS used for all statistical analyses.

Ethical Considerations

This study followed ethical guidelines to protect all participants. Informed consent was obtained from students and their parents, and participation was voluntary with no academic consequences for opting out. To ensure confidentiality, data were coded and stored securely, with results reported in group form only. All instruction and assessments aligned with the regular curriculum, and no harmful activities were involved. Approval was secured from school authorities and the Institutional Review Board (IRB). Standard procedures were followed during data collection and analysis, and students were later offered feedback on their performance and the study's findings.

III. Results and Discussion

It compares the results of the pre-test administered to the control and experimental groups before the application of the metacognitive intervention, and the post-test administered after using the intervention. The goal was to determine the effectiveness of the metacognitive strategies in improving students’ performance in Biology.

1. Comparison of the Pre-Test Results of the Control and Experimental Groups

Table 1
Comparison of the Pre-Test Results of the Control and Experimental Groups

Treatment	N	Mean	Tstat	P	Decision
Control	20	16.50	0.31	0.83	3.24
Experimental	20	16.20			

Table 1 shows that the experimental group had a mean pre-test score of 16.20, while the control group obtained a mean pre-test score of 16.50. Statistical analysis revealed that the null hypothesis should be accepted based on the obtained t-stat value of 0.31, which is lower than the critical value of t = 2.04. This indicates no significant difference in the mean test scores of the two groups, suggesting similar baseline knowledge levels before the intervention.

2. Comparison of the Pre-Test and Post-Test Results of the Control Group

A paired t-test was conducted to examine whether the students in the control group showed improvement after receiving traditional teaching methods.

Table 2
Pre-Test and Post-Test Scores of the Learners in the Control Group

Control	N	Mean	Tstat	Decision
Pre-Test	20	16.50	13.27	Significant
Post Test		28.10		

Table 2 indicates that the post-test scores of the students in the control group, with a mean score of 28.10, were significantly higher than the pre-test scores, which had a mean of 16.50. The obtained t-value of 13.27 is greater than the critical value of 2.04, suggesting that traditional teaching methods contributed to a significant improvement in the students' knowledge in Biology.

3. Comparison of the Pre-Test and Post-Test Results of the Experimental Group

A paired t-test was also used to analyze the pre-test and post-test scores of the experimental group, which received the metacognitive intervention.

Table 3
Pre-Test and Post-Test Scores of the Learners in the Experimental Group

Control	N	Mean	Tstat	Decision
Pre-Test	20	16.20	21.01	Reject Ho
Post Test		33.85		

Table 3 shows that the post-test scores of the students in the experimental group, with a mean of 36.40, were significantly higher than the pre-test scores, which had a mean of 16.20. The obtained t-value of 19.56 is much higher than the critical value of 2.04, suggesting that the metacognitive activities significantly improved the students' performances in Biology.

4. Post-Test Results of the Control and Experimental Groups After the Intervention

To assess whether the metacognitive activities resulted in a notable improvement in student performance, the post-test results of both the control and experimental groups were compared.

Table 4
Means of Post-Test Scores of the Learners in the Experimental and Control Groups

Treatment	N	Mean	Tstat	P	Decision
Control	20	28.10	3.24	0.001	Significant
Experimental	20	36.40			

The results in Table 4 support the effectiveness of the intervention. The mean post-test score of the experimental group (36.40) was significantly higher than that of the control group (28.10). The computed t-value of 4.84 exceeds the critical value of 2.04, with a p-value of 0.0001, which is lower than the 0.05 significance level. This indicates a significant improvement in the academic performances of the experimental group after participating in the metacognitive activities.

Additionally, observations during the study period revealed that students in the experimental group were highly engaged in classroom activities. They demonstrated improved self-awareness in their learning, actively applied strategies to monitor their understanding, and consistently made connections between new content and prior knowledge. This active involvement enhanced their metacognitive strategies, enabling them to perform better in Biology.

The students who participated in the metacognitive activities exhibited strong collaboration. They exchanged ideas, discussed concepts with peers, and linked their personal experiences to understand the lessons. In contrast, students in the control group, who were taught using traditional methods, showed less interaction and engagement during class.

In conclusion, the results suggest that incorporating metacognitive strategies into Biology instruction at Tyler High School significantly enhanced student learning, making the teaching and learning process more meaningful and impactful.

IV. Conclusion

The pre-test results confirmed that both the experimental and control groups started with comparable baseline knowledge in Biology. While the control group showed notable academic improvement through traditional lecture-based instruction, the experimental group demonstrated even greater gains after receiving metacognitive strategy-based instruction. Statistical analysis revealed a significant difference in post-test scores between the two groups, highlighting the effectiveness of metacognitive strategies in enhancing student performance. These results support the conclusion that integrating metacognitive activities fosters deeper learning and comprehension in Biology by encouraging students to actively manage their own learning.

REFERENCES

[1] Abdelghani, R., Law, E., Desvaux, C., Oudeyer, P.-Y., & Sauzéon, H. (2024). Interactive for training children's curiosity through the practice of metacognitive: a pilot study. arXiv preprint arXiv:2403.08397.https://arxiv.org/abs/2403.08397
[2] Abdelshiheed, M., Zhou, G., Maniktala, M., Barnes, T., & Chi, M. (2023). Metacognition and Motivation: The Role of Time-Awareness in Preparation for Future Learning. ArXiv preprint arXiv:2303.13541. https://arxiv.org/abs/2303.13541
[3] Abdelshiheed, M., Zhou, G., Maniktala, M., Barnes, T., & Chi, M. (2023). Metacognition and Motivation: The Role of Time-Awareness in Preparation for Future Learning. ArXiv preprint arXiv:2303.13541. https://arxiv.org/abs/2303.13541
[4] Akpan, J. P., & Beard, M. R. (2020). Challenges in teaching science in under-resourced schools: The role of infrastructure and materials. International Journal of Science Education, 42(7), 1145-1162.
[5] Akpan, J. P., & Beard, M. R. (2020). Challenges in teaching science in under-resourced schools: The role of infrastructure and materials. International Journal of Science Education, 42(7), 1145-1162.
[6] Ankita, & Khagendra, K. (2024). Metacognitive strategies in science education. *International Journal of Literacy
[7] Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition Implications for the design of computer-based scaffolds. Instructional Science, 33(5 6), 367-379.
[8] Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition—Implications for the design of computer-based scaffolds. Instructional Science, 33(5-6), 367-379. https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2024.1460496/full
[9] Benson, S. R. (2022). Metacognitive strategies in secondary science education. Montana State University. https://scholarworks.montana.edu/items/00798baa-7fde-4618-b7b1 8569bc285724
[10] Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). How people learn: Brain, mind, experience, and school. National Academy Press.
[11] Brown, S. A., & Green, T. D. (2020). The use of reflective journals in environmental science education. Journal of College Science Teaching, 49(3), 44–50.
[12] Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). Making Sense of Secondary Science: Research into Children's Ideas. Routledge.
[13] Duit, R., & Treagust, D. F. (2012). Conceptual Change: A Powerful Framework for Improving Science Teaching and Learning. International Journal of Science Education, 34(5), 574–591. https://doi.org/10.1080/09500693.2012.647697

[14] Education Endowment Foundation. (n.d.). Metacognition and self-regulation. Retrieved from https://educationendowmentfoundation.org.uk/education-evidence/teaching-learning-toolkit/metacognition-and-self-regulation
[15] Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. American Psychologist, 34(10), 906-911.
[16] Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. American Psychologist, 34(10), 906–911.
[17] Guzey, S. S., Harwell, M., & Moore, T. J. (2014). Development of an Instrument to Assess Teachers' Attitudes toward STEM Integration. Journal of Science Teacher Education, 25(1), 75–97. https://doi.org/10.1007/s10972-013-9361-3
[18] Johnson, B., & Sinatra, G. M. (2017). The influence of approach and avoidance goals of conceptual change. Journal of Educational Psychology, 109(6), 791–805.
[19] Johnson, B., & Sinatra, G. M. (2017). The influence of approach and avoidance goals on conceptual change. Journal of Educational Psychology, 109(6), 791–805.
[20] Kumar, H., Xiao, R., Lawson, B., et al. (2024). Supporting Self-Reflection at Scale with Large Language Models: Insights from Randomized Field Experiments in Classrooms. arXiv preprint arXiv:2406.07571. https://arxiv.org/abs/2406.07571
[21] Kumar, H., Xiao, R., Lawson, B., Musabirov, I., Shi, J., Wang, X., Luo, H., Williams, J. J., Rafferty, A., Stamper, J., & Liut, M. (2024). Supporting Self-Reflection at Scale with Large Language Models: Insights from Randomized Field Experiments in Classrooms. arXiv preprint arXiv:2406.07571. https://arxiv.org/abs/2406.07571
[22] Lee, M. J., & Baylor, A. L. (2016). Designing metacognitive prompts for computer-based learning environments. Educational Technology Research and Development, 64(5), 799–820.
[23] Lee, M. J., & Baylor, A. L. (2016). Designing metacognitive prompts for computer-based learning environments. Educational Technology Research and Development, 64(5), 799–820.
[24] Lee, O., & Buxton, C. A. (2010). Diversity and Equity in Science Education: Research, Policy, and Practice.Teachers College Press.
[25] Lemke, J. L. (2001). Articulating Communities: Sociocultural Perspectives on Science Education. Journal of Research in Science Teaching, 38(3), 296–316. https://doi.org/10.1002/1098-2736(200103)38:3<296::AID-TEA1007>3.0.CO;2-R
[26] Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-directed learning in problem based learning and its relationships with self-regulated learning. Educational Psychology Review, 20(4), 411–427.
[27] Madsen, J. L. (2017). Using metacognitive strategies to improve student performance and confidence in high school chemistry. Montana State University. https://scholarworks.montana.edu/items/b5c5cd40-721f-42f9-b886-d363fb3161b4
[28] Mason, A. J., & Singh, C. (2016). Impact of guided reflection with peers on the development of effective problem solving strategies and physics learning. arXiv preprint arXiv:1605.00025. https://arxiv.org/abs/1605.00025
[29] Mason, A. J., & Singh, C. (2016). Impact of guided reflection with peers on the development of effective problem solving strategies and physics learning. arXiv preprint arXiv:1605.00025. https://arxiv.org/abs/1605.00025
[30] National Center for Biotechnology Information. (2021). Metacognition and student learning outcomes /////////////in science education. Retrieved from https://pmc.ncbi.nlm.nih.gov/articles/PMC8734377/

[31] National Research Council. (2012). A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. National Academies Press.
[32] Osborne, J., & Dillon, J. (2008). Science Education in Europe: Critical Reflections. The Nuffield Foundation.
[33] Oxford Education Blog. (2021). Metacognitive strategies in the science classroom. Retrieved from https://educationblog.oup.com/secondary/metacognitive-strategies-in-the-science-classroom
[34] Patel, R., & Kim, S. (2016). Enhancing biology learning through metacognitive questioning strategies. Biochemistry and Molecular Biology Education, 44(2), 123–
[35] Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. Theory into Practice, 41(4), 219–225.
[36] Sadler, T. D., Sonnert, G., Hazari, Z., & Tai, R. (2013). Stability and Volatility of STEM Career Interest in High School: A Gender Study. Science Education, 96(3), 411–427. https://doi.org/10.1002/sce.21007
[37] Schraw, G., & Moshman, D. (1995). Metacognitive theories. Educational Psychology Review, 7(4), 351-371.
[38] Schraw, G., & Moshman, D. (1995). Metacognitive theories. Educational Psychology Review, 7(4), 351-371. doi:10.1007/BF02212307
[39] Schraw, G., & Moshman, D. (1995). Metacognitive theories. Educational Psychology Review, 7(4), 351-371. https://www.tandfonline.com/doi/full/10.1080/00219266.2025.2474986
[40] Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. Research in Science Education, 36(1–2), 111–139.
[41] Stanton, J. D., et al. (2015). Differences in metacognitive regulation in introductory biology students: when prompts are not enough. CBE—Life Sciences Education, 14(2), ar15. https://doi.org/10.1187/cbe.14-10-0172
[42] Stuever, D. M. (2006). The effect of metacognitive strategies on subsequent participation in the middle school science classroom. Wichita State University. https://soar.wichita.edu/items/ffde1f19-7f11-4d7f-ab7e-f1e682230453
[43] Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. Learning and Instruction, 4(4), 295–312.
[44] Talisayon, S. (2019). Issues and Challenges in Science Education: A Philippine Perspective. Philippine Journal of Science Education, 11(2), 25–35.
[45] Tanner, K. D. (2012). Promoting student metacognition. CBE—Life Sciences Education, 11(2), 113-120. https://www.lifescied.org/doi/10.1187/cbe.12-03-0033
[46] Tung, F. (2020). Teacher preparedness and the challenges of teaching science: A review of current practices and professional development needs. Science Education Review, 19(2), 45-61.
[47] Tung, F. (2020). Teacher preparedness and the challenges of teaching science: A review of current practices and professional development needs. Science Education Review, 19(2), 45-61.
[48] Tyler Idenpendent School District. Academic at Tyler ISD. www.tylerisd.org
[49] Van Opstal, M. T., & Daubenmire, P. L. (2015). Extending Students' Practice of Metacognitive Regulation Skills with the Science Writing Heuristic. International Journal of Science Education, 37(7), 1089–1112. https://doi.org/10.1080/09500693.2015.1019385

[50] Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. Metacognition and Learning, 1(1), 3–14.
[51] Veenman, M. V. J., Van Hout-Wolters, B. H., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. Metacognition and Learning, 1(1), 3-14.
[52] Verenikina, I. (2018). The role of technology in science education. Educational Technology Research and Development, 66(3), 603-615.
[53] Verenikina, I. (2018). The role of technology in science education. Educational Technology Research and Development, 66(3), 603-615.
[54] Wang, H., & Chen, L. (2022). The Role of Metacognitive Strategy Use in Enhancing Astronomy Learning. International Journal of Science Education, 44(1), 58–72.
[55] White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. Cognition and Instruction, 16(1), 3–118.
[56] Yore, L. D., Anderson, J. O., & Shymansky, J. A. (2007). Examining the Literature Base in Science Literacy from 1980 to 2003. Journal of Research in Science Teaching, 42(8), 922–938. https://doi.org/10.1002/tea.20082
[57] Yuen, S. K., & Fong, M. L. (2019). Addressing achievement gaps in science education: The role of socioeconomic and cultural factors. Educational Research and Practice, 34(3), 85-98.
[58] Yuen, S. K., & Fong, M. L. (2019). Addressing achievement gaps in science education: The role of socioeconomic and cultural factors. Educational Research and Practice, 34(3), 85-98.
[59] Zimmerman, B. J., & Schunk, D. H. (2011). Self-regulated learning and academic achievement: Theoretical perspectives (2nd ed.). Routledge.
[60] Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. Studies in Science Education, 49(2), 121-169.
[61] Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. Studies in Science Education, 49(2), 121–169.
[62] Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. Studies in Science Education, 49(2), 121-169. doi:10.1080/03057267.2013.847261
[63] Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. Studies in Science Education, 49(2), 121-169. /https://www.researchgate.net/publication/321475973_Students%27_Metacognition_an////////
///d_Metacognitive_Strategies_in_Science_Education
[64] Zohar, A., & Barzilai, S. (2015). A review of research on metacognition in science education: current and future directions. Studies in Science Education, 51(2), 169–211.