A STUDY ON THE EFFECT OF METACOGNITIVE INSTRUCTIONAL STRATEGIES IN PROMOTING PROBLEM-SOLVING SKILLS AMONG SECONDARY STAGE STUDENTS

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DECLARATION

I hereby declare that the dissertation entitled **A STUDY ON THE EFFECT OF METACOGNITIVE INSTRUCTIONAL STRATEGIES IN PROMOTING PROBLEM-SOLVING SKILLS AMONG SECONDARY STAGE STUDENTS** has been carried out by me during the academic year 2023-2025 in partial fulfilment of the requirements for the award of the Two-Year Degree of Master of Education (M.Ed.) from Barkatullah University, Bhopal, Madhya Pradesh.

The study has been conducted under the guidance and supervision of **Dr. Manju**, Associate Professor, Department of Education, Regional Institute of Education, Bhopal, Madhya Pradesh.

It is also declared that the research work done by me is original to the best of my knowledge. This dissertation has not been submitted by me for award of any other degree or diploma in Barkatullah University, Bhopal or any other University.

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CERTIFICATE

This is to certify that the dissertation entitled **A Study on the Effect of Metacognitive Instructional Strategies in Promoting Problem-Solving Skills among Secondary Stage Students** being submitted by **MANSEE SINGH**, a student of Master of Education (M.Ed.) bearing Roll number-2406600314 and Enrolment Number-R240660590007, Regional Institute of Education, NCERT, Bhopal, M.P., is a Bonafide student and this research is carried by her in the department of Education under my supervision and guidance. The work is original to the best of her knowledge and it has not been submitted earlier in any form for any degree at any university by her.

This is further certified that the dissertation in its present form is fit for submission to Barkatullah University for the award of the degree of Two-year M.Ed. program.

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LIST OF ABBREVATIONS

MAI	Metacognitive Awareness Inventory
CBSE	Central Board of Secondary Education
DMS	Demonstration Multipurpose School
NEP 2020	National Education Policy 2020
NCF 2005	National Curriculum Framework 2005
NCERT	National Council of Educational Research and Training
OECD	Organisation for Economic Co-operation and Development
UNESCO	United Nations Educational Scientific and Cultural Organization
SDG	Sustainable Developmental Goals
SDG 4.7	A Sub-goal of SDG 4 focusing on Education for Sustainable Development, Global Citizenship and Cultural Diversity
ATP	Adenosine Triphosphate
DNA	Deoxyribonucleic Acid
RNA	Ribonucleic Acid
KWL	Know–Want–Learn (strategy)

CHAPTER-1

INTRODUCTION

1. INTRODUCTION

1.1. INTRODUCTION:

1.1.1. Background of the Study

The rapid transformation of the global educational landscape in the 21st century has redefined the core competencies required for academic and professional success. Problem-solving, once considered a peripheral or supplemental skill, has now become a central pillar of school curricula around the world (OECD, 2018). As societies grapple with increasingly complex challenges—including climate change, public health crises, automation, and shifting labor markets—the ability to think critically, solve unstructured problems, and continuously adapt has moved from the margins to the forefront of educational priorities. Consequently, the traditional emphasis on rote memorization, passive reception of information, and standardized assessment is being fundamentally reconsidered in favor of frameworks that nurture adaptive expertise, cognitive flexibility, and strategic thinking (Trilling & Fadel, 2009).

In this era marked by rapid technological disruption, socio-economic volatility, and cultural interconnectedness, learners are expected not just to retain static knowledge but to navigate dynamic and novel situations with confidence and creativity. The capacity to make decisions under uncertainty, work collaboratively across disciplines, and engage in reflective inquiry is no longer confined to higher education or specialized fields—it is now expected from students as early as the secondary level. As a result, educational systems are under increasing pressure to equip learners with transferable skills that are applicable across multiple domains and life contexts.

Within this evolving paradigm, instructional strategies must undergo a parallel transformation. Education is no longer about simply delivering content; it is about cultivating learners who can make meaning from information, challenge assumptions, and direct their own cognitive growth. Herein lies the increasing relevance of metacognitive instructional strategies—pedagogical approaches that explicitly teach students to **think about, monitor,** and **regulate** their own thinking processes. These strategies help students become more aware of how they learn, why certain approaches work or fail, and what steps they can take to optimize their learning outcomes. In doing so, metacognitive instruction provides the scaffolding for learners to become self-directed, reflective, and resilient thinkers, capable of navigating both academic and real-world challenges.

Moreover, the shift toward metacognitive teaching practices aligns with advancements in cognitive and educational psychology, which underscore the central role of metacognition in effective learning. Neuroscientific research suggests that executive functions such as planning, goal setting, and self-monitoring—cognitive processes closely linked to metacognition—are critical for sustained academic achievement and long-term cognitive development. These findings reinforce the idea that metacognitive capacity is not an innate trait but a teachable and learnable set of skills, which can and should be systematically integrated into school curricula from an early stage.

In addition to its cognitive benefits, metacognitive instruction has significant implications for educational equity and inclusion. Students from disadvantaged backgrounds often face systemic barriers to academic success, including limited access to academic support, unfamiliarity with strategic learning behaviors, and reduced self-efficacy. By making learning processes explicit and teachable, metacognitive strategies level the playing field, providing all students—regardless of socio-economic status—with tools to take control of their own learning trajectories. When embedded into regular instruction, these strategies promote not only academic achievement but also learner empowerment, motivation, and agency.

Furthermore, global educational policy frameworks have begun to reflect the urgency of these pedagogical shifts. The OECD Learning Compass 2030 advocates for future-oriented education that emphasizes student agency, reflection, and well-being as foundational elements of learning. Similarly, UNESCO's Sustainable Development Goal 4 prioritizes inclusive and equitable quality education that fosters lifelong learning opportunities for all—goals that are inherently supported by metacognitive instruction. At the national level, policies such as India's National Education Policy (NEP) 2020 call for a transformation of schooling from exam-centric, content-heavy instruction to holistic, learner-centered, and skills-driven education, wherein "learning how to learn" is seen as a core objective (Ministry of Education, 2020).

To further support this shift, specific science subjects like biology, chemistry, and physics are increasingly adopting inquiry-based and conceptually rich pedagogies. For example, in biology, topics such as photosynthesis and respiration involve abstract reasoning, data interpretation, and model construction—skills that benefit greatly from the application of metacognitive strategies.

Thus, in light of global trends, educational psychology, and national reform agendas, the integration of metacognitive instructional strategies emerges as both a pedagogical imperative and a moral necessity. These strategies enable learners to become architects of their own understanding, develop lifelong learning habits, and thrive in an increasingly volatile, uncertain, complex, and ambiguous (VUCA) world. The present study builds upon this foundational understanding by examining the specific application and impact of metacognitive instruction in the context of secondary science education, aiming to contribute empirically grounded insights to the broader discourse on educational transformation.

1.1.2. Conceptual Framework: Understanding Metacognition

The term metacognition was first introduced by John Flavell (1979), who described it as “knowledge and cognition about cognitive phenomena.” In essence, metacognition involves an individual's ability to reflect on, understand, and control their cognitive processes. It has since become a central construct in educational and cognitive psychology, recognized for its powerful influence on how individuals learn, solve problems, and adapt strategies across various learning environments.

Metacognition encompasses two interrelated components: metacognitive knowledge and metacognitive regulation (Schraw & Moshman, 1995). Metacognitive knowledge refers to one's awareness of their cognitive abilities, the characteristics of different tasks, and the strategies that may be employed to accomplish those tasks. It includes three dimensions: declarative knowledge (knowing what strategies are), procedural knowledge (knowing how to use them), and conditional knowledge (knowing when and why to apply them). For instance, a student may know that making diagrams helps in understanding biology processes (declarative), be able to draw them correctly (procedural), and choose this method when studying for complex topics like cellular respiration (conditional).

Metacognitive regulation, on the other hand, involves the active control of cognitive processes through planning (setting goals and selecting strategies), monitoring (tracking comprehension and progress), and evaluation (assessing the effectiveness of strategies and outcomes). These processes are essential for problem-solving in science, where a learner might plan an approach to an experiment, monitor understanding of results, and evaluate whether the hypothesis was supported.

When students are equipped with these metacognitive capacities, they are better able to allocate attention, manage their cognitive load, anticipate difficulties, and flexibly adjust their approach based on feedback and task demands. Such capabilities are particularly crucial in complex learning tasks, such as scientific inquiry, problem-solving in mathematics, or analytical reading, where success depends on more than just content knowledge—it requires strategic engagement and self-awareness.

Within the classroom context, metacognitive instruction refers to teaching strategies that explicitly develop students' awareness and regulation of their own thinking. This instructional approach is foundational to fostering self-regulated learning (SRL)—a process whereby learners become active participants in their education, setting their own learning goals, selecting and implementing strategies, monitoring their performance, and reflecting on outcomes to make informed adjustments (Zimmerman, 2002).

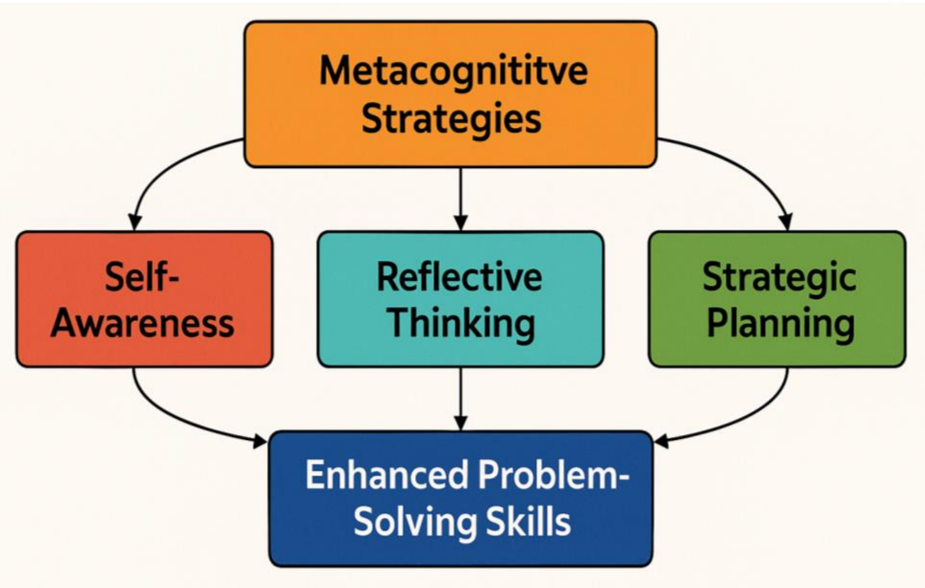

Fig. 1.1. - Metacognitive Strategies

Fig. 1.1. demonstrates that self-awareness, reflective thinking, and strategic planning—key aspects of metacognitive strategies—collectively contribute to improved problem-solving abilities. Each component is interconnected, illustrating that the synergy between these strategies is vital for effective learning.

Schraw and Dennison (1994), in their widely cited model, operationalized metacognitive ability into measurable components including goal-setting, strategic planning, comprehension monitoring, and outcome evaluation. These dimensions are interdependent and collectively contribute to the learner's ability to engage in deliberate, reflective, and purposeful learning. For example, a student engaging in a physics problem might plan their approach by recalling relevant formulas (planning), assess their understanding as they work through the steps (monitoring), and determine whether their final answer is reasonable based on the context (evaluation).

Developmentally, metacognitive abilities begin to emerge in late childhood but become increasingly sophisticated during adolescence—a period that coincides with secondary schooling (Veenman et al., 2006). This makes the secondary stage an opportune period to cultivate metacognitive habits, especially in academic subjects like science that require abstract reasoning, hypothesis testing, and integration of concepts.

Research has shown that explicit instruction in metacognitive strategies leads to measurable improvements in academic outcomes across domains. Learners taught to reflect on their problem-solving processes tend to outperform those who receive content-only instruction (Dignath & Büttner, 2008). Moreover, metacognitive awareness has been linked to increased academic resilience, motivation, and self-efficacy, as students gain confidence in their ability to regulate their learning even in the face of challenges.

From a pedagogical standpoint, metacognitive instruction demands a shift in the teacher's role—from knowledge transmitter to cognitive coach. Teachers must model thinking processes, scaffold strategic behavior, and create opportunities for students to practice and reflect on their learning. This includes embedding prompts for self-questioning, integrating formative assessments that elicit metacognitive reflection, and encouraging peer collaboration to externalize thinking.

Furthermore, metacognitive instruction aligns seamlessly with constructivist theories of learning, which posit that learners build knowledge through active engagement and internal restructuring. By emphasizing reflection, self-assessment, and adaptation, metacognitive strategies create a learning environment that values depth over breadth, process over product, and growth over performance.

Given these theoretical and empirical foundations, the incorporation of metacognitive instruction is not only beneficial but essential for preparing learners to navigate the demands of an increasingly complex, knowledge-driven world. It equips them not only with the tools to solve academic problems but also with the capacity to learn independently and adaptively throughout life.

1.1.3. Relevance to Secondary Science Education

At the secondary stage of education—typically encompassing learners aged 14 to 18—cognitive development advances significantly, enabling students to shift from concrete operational thinking to more abstract, formal-operational reasoning (Zimmerman & Schunk, 2011). According to Piagetian developmental theory, this period is marked by a growing ability to engage in hypothetical-deductive reasoning, systematic analysis, and complex problem-solving. This transition provides a critical developmental window for cultivating metacognitive capacities, as students are cognitively prepared to not only process information but also to reflect upon and regulate their learning strategies.

In this context, science education presents a uniquely fertile ground for integrating metacognitive instruction. The discipline of science, whether in physics, chemistry, biology, or environmental studies, demands not just the retention of factual information, but also a deep understanding of concepts, logical sequencing of procedures, and evaluation of evidence. Students are frequently required to form hypotheses, interpret experimental data, engage in cause-effect reasoning, and make inferences—cognitive operations that inherently benefit from metacognitive regulation.

Metacognitive awareness allows science learners to plan their approach to a problem, monitor their comprehension of theoretical principles, and evaluate the appropriateness of their solutions. For instance, while solving a complex chemical equation or analyzing a physics-based motion problem, students with metacognitive training are better positioned to assess their understanding, troubleshoot errors in logic, and apply alternative strategies when needed. This internal dialogue between cognition and regulation is crucial in enabling scientific thinking, where answers are often non-linear and require iteration and reflection.

Despite the cognitive demands of science education, classroom practices in many parts of India remain anchored in content transmission models that prioritize textbook-based instruction, factual recall, and examination-driven learning. According to the National Curriculum Framework (NCERT, 2005), science education in India has historically emphasized the memorization of laws, definitions, and formulas, often at the expense of nurturing inquiry, exploration, and critical thinking. As a result, students may perform well on standardized tests yet struggle with real-world application, conceptual integration, and creative problem-solving.

This gap between curriculum intention and classroom reality poses significant challenges. The overemphasis on factual recall discourages deeper engagement with scientific ideas and inhibits the development of higher-order thinking skills. Furthermore, traditional assessment formats—dominated by multiple-choice and short-answer questions—rarely measure metacognitive processes such as planning or self-correction. Consequently, students are rarely given opportunities to reflect on their thinking, evaluate their problem-solving strategies, or revise their approach based on feedback.

Introducing metacognitive instructional strategies into secondary science education can help shift this dynamic. By embedding reflection prompts, strategy modeling, and self-assessment tools into science lessons, educators can transform passive content delivery into active, learner-centered engagement. For example, after conducting a lab experiment, students can be guided to reflect on their hypothesis formulation, assess the accuracy of their data interpretation, and consider how their method could be improved. Such practices not only enhance conceptual understanding but also promote scientific literacy—the ability to think and reason like a scientist.

Moreover, metacognitive strategies are particularly useful for bridging performance gaps among diverse learners. Science education often presents steep conceptual challenges that can overwhelm students who lack effective learning strategies. Through structured metacognitive instruction, these students gain tools for organizing content, breaking down complex problems, and navigating ambiguity—skills that are essential not only for science learning but for academic resilience more broadly.

Importantly, the relevance of metacognition in science education is not confined to high-performing students. Research has shown that even average or struggling learners show significant gains when taught how to think about their thinking. In a study by Vula et al. (2017), elementary and middle-grade students who received metacognitive training demonstrated improved performance in scientific tasks and reported increased confidence in their ability to solve problems. These findings underscore the inclusivity of metacognitive approaches, which can be tailored to support learners across the academic spectrum.

In sum, the secondary stage of science education presents an opportune and necessary context for the integration of metacognitive instruction. It aligns with students' cognitive readiness, addresses core challenges in science pedagogy, and contributes to the development of autonomous, reflective learners capable of meeting the demands of both academic and real-world problem-solving. In doing so, it supports not only curriculum reform but also the broader educational goal of preparing students for a future in which critical thinking, adaptability, and innovation are essential.

1.1.4. Policy Support and Global Educational Alignment

The imperative to integrate metacognitive instructional strategies into classroom teaching is increasingly supported by both national and international educational policy frameworks. These policies advocate for a shift from traditional rote-based education to a learner-centered model that cultivates critical thinking, reflection, and independent learning—core components of metacognition.

At the global level, the OECD's Learning Compass 2030 emphasizes the importance of student agency, co-agency, and transformative competencies. Central to this model is the concept of "learning to learn," which aligns directly with metacognitive development. Students are encouraged not just to acquire knowledge but to continuously reflect on how they acquire, process, and apply it in diverse contexts. Metacognitive skills, such as self-monitoring and strategic planning, are recognized as fundamental for preparing learners to navigate rapid societal and technological changes.

Similarly, UNESCO's Sustainable Development Goal 4 (SDG 4) envisions inclusive and equitable quality education for all, emphasizing the development of skills that support lifelong learning. Metacognitive strategies are especially relevant here, as they empower learners to take ownership of their learning journeys, adapt to new challenges, and become self-sufficient problem-solvers. By fostering reflective thinking, metacognition contributes directly to achieving SDG 4.7, which highlights the need to promote education for sustainable development, global citizenship, and appreciation of cultural diversity.

Within the Indian context, the National Education Policy (NEP) 2020 marks a significant reform in educational philosophy. It calls for a transformation from content-heavy instruction and summative assessment to a more competency-based, holistic, and flexible approach. One of the NEP's central tenets is the cultivation of higher-order cognitive skills—particularly critical thinking, creativity, and problem-solving—which are inextricably linked to metacognition. The policy explicitly mentions the goal of developing the ability to reflect, question, and evaluate as part of foundational literacy and numeracy, and across subject areas.

The NEP 2020 also proposes the integration of experiential learning, inquiry-based pedagogy, and formative assessments—approaches that naturally incorporate metacognitive strategies. For instance, activities like self-reflection journals, peer assessments, and project-based learning not only deepen subject understanding but also enhance students' awareness of their learning processes.

At the implementation level, various Indian educational bodies such as the NCERT and CBSE have begun to include elements of metacognition in their guidelines and textbooks. The CBSE's pedagogical plans encourage reflective teaching practices and stress the importance of feedback, self-assessment, and student agency. For example, the CBSE's assessment frameworks increasingly include rubrics and portfolios that prompt students to evaluate their own progress and set learning goals.

The relevance of these policy shifts becomes even more pronounced in the context of science education. Inquiry-based learning, a key recommendation of both NEP 2020 and international best practices, demands metacognitive engagement. When students design experiments, hypothesize outcomes, and interpret findings, they must engage in planning, monitoring, and evaluating—the three pillars of metacognitive regulation.

In addition to cognitive alignment, metacognitive instruction also serves broader socio-emotional goals outlined in educational policy. It supports mental well-being by reducing academic anxiety, fostering a sense of control, and promoting resilience—traits identified as essential for thriving in uncertain futures.

In conclusion, the growing endorsement of metacognitive instructional strategies in national and global education policies reflects a deeper understanding of how students learn best in the 21st century. By integrating these strategies into science education, the present study not only aligns with policy mandates but also addresses the evolving educational needs of students, preparing them to become thoughtful, adaptive, and independent learners in a complex world.

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1.1.5. Empirical Support for Metacognitive Instructional Strategies

Over the past three decades, a robust body of empirical research has consistently demonstrated the efficacy of metacognitive instructional strategies in improving academic performance, learning outcomes, and student engagement across educational levels and disciplines. These studies provide compelling evidence that metacognitive instructional strategies—when intentionally and systematically implemented—enhances not only content mastery but also students' ability to think independently, reflectively, and strategically.

One of the foundational studies in this domain, conducted by Wang, Haertel, and Walberg (1990), performed a meta-analysis of factors influencing learning and concluded that metacognitive regulation was among the most powerful predictors of academic success. Students who engaged in planning, monitoring, and evaluating their thinking exhibited superior retention and deeper comprehension compared to their peers who relied solely on rote or surface-level strategies. These findings were later substantiated by Jiang, Ma, and Gao (2016), whose quasi-experimental study involving 90 middle school students revealed that explicit training in metacognitive strategies led to marked improvements in students' concentration, self-awareness, academic confidence, and strategic flexibility, especially in cognitively demanding environments.

Evidence of metacognitive instructional strategies effectiveness is particularly strong in domain-specific contexts, where learners are required to apply content knowledge to solve complex problems. In the field of language education, Rahman (2010) found through a qualitative study of 60 secondary students that high-performing learners made more deliberate use of metacognitive tools such as goal-setting, self-monitoring, and post-task reflection. These students adapted more effectively to linguistic challenges and transferred their learning strategies across tasks, indicating a higher level of cognitive autonomy.

In mathematics education, Kazemi (2012) conducted a mixed-method study with 120 high school students, revealing a significant positive correlation between metacognitive awareness and mathematical problem-solving capabilities. Velázquez Tejeda and Goñi-Cruz (2024), using structured interviews and achievement tests with a sample of 75 students, similarly observed that learners with strong metacognitive skills employed diverse strategies, persisted through challenges, and evaluated alternative solutions more effectively. The latter study also highlighted the importance of teacher-scaffolded dialogue and structured reflection in promoting metacognitive growth in under-resourced classrooms.

The benefits of metacognitive instructional strategies extend into science education as well. Joel (2016), in a quasi-experimental study involving 80 secondary chemistry students, compared analogy-based instruction with concept-mapping strategies—both of which incorporated metacognitive elements. The study concluded that concept mapping led to more consistent learning gains across gender and ability levels, underscoring the inclusivity of metacognitive approaches in addressing diverse learner needs.

Younger students also benefit significantly from metacognitive instructional strategies. Vula, Avdyli, Berisha, and Saqipi (2017) implemented a teaching model grounded in metacognitive principles in elementary classrooms and found statistically significant improvements in students' ability to reason, self-assess, and articulate their thought processes. Even students in lower primary grades showed notable enhancements in metacognitive awareness and academic performance when exposed to consistent strategy instruction, demonstrating that metacognition is both teachable and developmentally adaptable.

Interdisciplinary studies further reinforce the cross-curricular value of metacognition. McKim and McKendree (2020), working with undergraduate students in agricultural and environmental sciences, found through a longitudinal case study that those trained in metacognitive reflection outperformed their peers in systems-level problem-solving tasks. These findings reinforce the relevance of metacognitive instruction in domains that integrate theoretical knowledge with practical application.

In international contexts, Bal and Doğanay (2022) studied 100 Turkish secondary school students and found that those with higher metacognitive awareness were significantly more effective in solving geometry problems. Their study used a pre-test/post-test control group design and found that metacognitive learners were better at adjusting strategies mid-task, detecting errors, and validating their reasoning—evidence of the self-regulatory power of metacognition. The study also highlighted the role of classroom environment and teacher modelling in fostering these skills.

In a study on stoichiometry by Panganayi (2018), involving 60 high school students, structured support such as guided reflection templates and error analysis checklists led to deeper conceptual understanding and improved performance. Interestingly, these gains were observed even among students who could not explicitly articulate metacognitive terminology, suggesting that the cognitive benefits of such strategies can occur implicitly through consistent instructional integration.

Taken together, these empirical findings offer strong, multi-contextual validation for the implementation of metacognitive instruction as a means to enhance problem-solving, learning efficiency, and academic self-efficacy. They highlight that the metacognitive instructional strategies:

- Are effective across subject areas including science, mathematics, language learning, and applied disciplines.
- Benefit diverse groups of students—including those from underperforming, disadvantaged, or mixed-ability backgrounds.
- Contribute to deeper learning by fostering student agency, reflection, and strategic thinking.
- Are developmentally appropriate across age groups and scalable for both primary and secondary education.

Given this extensive empirical support, it is evident that metacognitive instructional strategy is not only theoretically robust but practically impactful. As such, integrating these strategies into secondary science classrooms in India holds substantial promise for improving both academic outcomes and the broader goal of preparing reflective, autonomous learners for the demands of the 21st century.

1.1.6. Existing Gaps in Implementation

Despite the robust theoretical foundations and extensive empirical validation of metacognitive instructional strategies, their actual integration into Indian classrooms—particularly within Central Board of Secondary Education (CBSE)-affiliated schools—remains markedly limited. While educational policies such as the National Education Policy (NEP) 2020 emphasize reflective and student-centered pedagogy, classroom realities often diverge sharply from these aspirations. The prevailing instructional culture continues to be predominantly didactic, with an overwhelming reliance on textbook-centric, lecture-based teaching methods that leave little room for student agency, metacognitive reflection, or strategic thinking.

In most secondary classrooms, especially in science education, the teaching-learning process is narrowly aligned with summative assessments, which primarily reward factual recall and procedural fluency. As a result, the emphasis remains on completing syllabus content, often at the expense of engaging learners in meaningful cognitive or metacognitive activities. The pressure of high-stakes board examinations further entrenches this approach, leading educators to prioritize coverage over depth, and correctness over reflection. In such an environment, opportunities for students to practice self-monitoring, goal-setting, strategy adaptation, or post-task evaluation—key elements of metacognitive regulation—are minimal or entirely absent.

A critical barrier to implementation lies in teacher preparedness and professional development. Most pre-service teacher education programs and in-service training workshops in India continue to focus on content delivery and classroom management, with limited exposure to advanced instructional design or cognitive science principles. Consequently, many teachers are either unfamiliar with the concept of metacognition or lack practical knowledge about how to embed metacognitive strategies into their daily teaching routines. Even when teachers recognize the value of promoting reflective learning, they often report being constrained by rigid curricula, insufficient instructional time, and pressure to meet performance metrics (NCERT, 2017).

Furthermore, curricular and textbook materials seldom include explicit references to metacognitive instructional strategies. While certain activities may encourage higher-order thinking, they are rarely accompanied by scaffolding that prompts learners to reflect on their thought processes, assess their comprehension, or plan future learning strategies. The absence of instructional frameworks or classroom tools—such as reflection journals, learning logs, strategic questioning techniques, or metacognitive prompts—means that even well-intentioned teachers lack the structural support to foster such skills.

Another systemic limitation stems from assessment practices that continue to privilege rote memorization over conceptual understanding or process-based reasoning. Most classroom tests and board examination formats do not assess students' ability to explain their thinking, justify their problem-solving approach, or evaluate multiple strategies. In the absence of such metacognitively rich assessments, both teachers and students are discouraged from investing in reflective or strategic learning behaviors. The disconnect between learning objectives and assessment criteria creates a misalignment that hinders the development of self-regulated learners.

Regional and infrastructural disparities further exacerbate this challenge. In many rural and semi-urban schools, the focus remains on basic content delivery due to constraints such as large class sizes, limited digital access, and resource limitations. In such settings, innovative pedagogical practices—including metacognitive instruction—are often viewed as idealistic or impractical. Teachers in these areas may also lack exposure to professional learning communities, mentoring systems, or digital platforms that could facilitate pedagogical innovation and capacity building.

Moreover, there exists a policy-practice divide, wherein educational reforms are articulated in policy documents but not adequately translated into classroom practice. While the NEP 2020 and NCERT learning outcomes advocate for critical thinking, problem-solving, and reflective learning, there is limited guidance on how these competencies should be operationalized within the constraints of existing school systems. The absence of implementation roadmaps, accountability mechanisms, and longitudinal teacher support systems means that promising pedagogical models often fail to move beyond the level of theoretical endorsement.

Finally, there is a noticeable lack of localized, context-specific research on metacognitive instructional strategies within Indian secondary schools. Much of the available literature is either international or derived from small-scale experimental studies that do not fully reflect the diversity, complexity, and constraints of real Indian classrooms. As a result, school leaders and educators have limited access to evidence-based models or best-practice case studies that could inform their efforts to integrate metacognitive strategies into mainstream education.

To overcome these barriers, a multi-pronged and scalable implementation framework must be developed. Firstly, comprehensive professional development programs are essential. These should go beyond theoretical workshops to include hands-on training, collaborative lesson planning, peer observation, and mentoring systems focused on strategy integration. Teacher educators and academic coordinators must be equipped with examples, case studies, and classroom-tested tools to bridge theory with actionable practice.

Secondly, curriculum designers and textbook authors must embed metacognitive components systematically within lesson plans and activity templates. Each science lesson can include guiding questions such as "What do I already know about this topic?", "How will I approach this problem?", and "What can I do differently next time?" Such prompts help internalize the planning-monitoring-evaluating cycle central to metacognitive regulation.

Thirdly, assessment frameworks should be redesigned to reward not only correct answers but also strategic thinking, reasoning, and reflection. Rubrics can be introduced in science tasks to evaluate how well students plan, justify, and evaluate their problem-solving methods. Formative assessments like learning journals, reflection sheets, and peer reviews should be integrated to promote metacognitive habits.

Fourth, pilot programs and action research initiatives must be encouraged at the school level. These can be supported by district education offices, teacher training institutions, or NGOs working in school improvement. Documentation and sharing of these initiatives can create a repository of context-sensitive innovations, empowering educators to adapt strategies to their own teaching environments.

Lastly, schools must foster a reflective institutional culture. Leadership teams should allocate time in staff meetings and classroom schedules for reflection and metacognitive discourse. Recognition of teacher-led innovations, student self-assessment practices, and peer collaboration can build a sustained community of practice.

In conclusion, while the value of metacognitive instructional strategies is widely acknowledged in scholarly and policy discourse, systemic, institutional, pedagogical, and infrastructural barriers continue to impede its widespread implementation in Indian secondary education. Addressing these gaps will require a multi-level strategy encompassing curriculum reform, teacher capacity-building, assessment innovation, and localized action research. With targeted and sustained interventions, the transformative potential of metacognitive instruction can be realized, equipping students to become reflective, autonomous learners capable of thriving in a complex and ever-evolving world. Bridging these gaps requires systemic support, targeted teacher development, curricular innovation, and a cultural shift toward reflective and student-centered learning. The present study seeks to explore these dynamics in the context of secondary science education in India, with the goal of identifying actionable strategies for integrating metacognitive instructional strategy effectively and sustainably. As such, integrating these strategies into secondary science classrooms in India holds substantial promise for improving both academic outcomes and the broader goal of preparing reflective, autonomous learners for the demands of the 21st century.

1.2. RATIONALE OF THE STUDY:

In today's rapidly evolving world, the very definition of what it means to be "educated" has shifted. The 21st-century learner is not merely expected to remember facts or follow instructions—they are expected to think critically, solve novel problems, collaborate with others, and engage with knowledge in meaningful, transferable ways. The rise of complex societal challenges such as climate change, technological disruption, and socio-economic inequality has only deepened this expectation. Education must now foster ***learning how to learn***, a competency that lies at the heart of metacognitive development.

In this context, the role of instructional strategies that go beyond content delivery is becoming increasingly essential. **Metacognitive instructional strategies**—which emphasize planning, monitoring, and evaluating one's own thinking and learning—serve as a powerful framework for enabling students to become more self-directed, strategic, and adaptive learners. These strategies are not just tools for academic improvement, but foundational life skills that empower learners to navigate ambiguity, reflect on challenges, and persist through failure.

Although theoretical research and policy frameworks (such as the National Education Policy 2020 and OECD's Learning Compass 2030) strongly advocate for reflective and learner-centered pedagogies, **practical implementation remains limited**, especially in Indian classrooms. The teaching-learning process still largely revolves around rote learning, examination-oriented teaching, and one-way knowledge transmission. Teachers, often constrained by rigid curricula and lack of training, seldom embed metacognitive thinking into everyday practice.

This disconnect is further compounded by an **evident research gap**. Most existing studies on metacognition are either conducted in Western or highly urban contexts, or they target younger learners at the elementary level. Very few empirical investigations focus on how **secondary school students in Indian classrooms internalize and apply metacognitive strategies**, particularly in real classroom environments. Even fewer studies explore how these strategies influence higher-order skills like problem-solving, creativity, critical thinking, and independent learning across **multiple subjects**—not just in science but also in mathematics, social studies, or language learning.

Furthermore, there is a **need to address the equity dimension of education**. Learners from diverse socio-economic and linguistic backgrounds may lack familiarity with effective study strategies and self-regulation skills. Metacognitive instruction has been shown to mitigate these disadvantages by making learning processes transparent, structured, and accessible to all students.

The urgency of these reforms became especially apparent during the COVID-19 pandemic, which revealed the limitations of traditional schooling and the growing need for students to **regulate their own learning independently**. Students with higher metacognitive awareness adapted better to remote education, engaged meaningfully with online content, and exhibited resilience in the face of academic uncertainty.

Against this backdrop, the **present study was conceptualized to respond to these multidimensional needs and gaps**. It is rooted in the belief that metacognitive instruction can bridge the gap between content acquisition and conceptual understanding, between passive consumption and active engagement. Specifically, the study aims to explore:

- What metacognitive strategies like planning, goal-setting, comprehension monitoring, and evaluation can improve **students' ability to learn strategically and solve problems independently**.
- How students from a **semi-urban educational context** respond to such instructional practices.
- How these strategies can contribute to the **development of core 21st-century skills**—including critical thinking, creativity, collaboration, and decision-making.

The significance of this study lies not only in its potential to improve academic outcomes, but also in its relevance to teachers, curriculum developers, and education policymakers. It provides **empirical evidence and classroom-based insights** into how metacognitive strategies can be integrated into day-to-day instruction in a way that is scalable, inclusive, and aligned with broader educational goals.

By transforming the classroom from a site of passive instruction into a space for **thinking about thinking**, this study supports a larger pedagogical vision—one where learners take ownership of their learning journeys, reflect on their growth, and emerge as competent, compassionate, and cognitively empowered individuals ready to thrive in an ever-changing world.

1.3. STATEMENT OF THE RESEARCH:

A Study on the Effect of Metacognitive Instructional Strategies in Promoting Problem-Solving Skills among Secondary Stage Students

1.4. OPERATIONAL DEFINITION:

1.4.1. Metacognitive Instructional Strategies refer to teaching methods intentionally designed to develop students' awareness of their own thinking processes and to help them plan, monitor, and evaluate their learning (e.g., Think-Aloud, KWL, etc.). These strategies include activities that promote reflection, self-questioning, goal-setting, and strategic thinking during academic tasks.

1.4.2. Problem-solving Skills are defined as the students' ability to analyse situations, apply logical reasoning, and develop effective solutions to complex and unfamiliar challenges within academic contexts, particularly in science education.

1.4.3. Secondary Stage Students are the students aged between 14 and 18 years who are enrolled in secondary schools affiliated with the Central Board of Secondary Education (CBSE) in the Bhopal district of Madhya Pradesh.

1.5. DELIMITATION OF THE STUDY

1.5.1. This study had been delimited to secondary school students aged between 14 to 18 years who were enrolled in CBSE-affiliated government senior secondary schools located in the Bhopal district of Madhya Pradesh

1.5.2. Present study had been delimited to the Biology subject only.

1.6. OBJECTIVES OF THE STUDY

1.6.1. To assess the awareness level of metacognitive instructional strategies among secondary stage students before and after the intervention of independent variable.

1.6.2. To compare the difference between the mean scores of problem-solving skills between students taught using metacognitive instructional strategies and those taught using traditional teaching methods.

1.6.3. To study the correlation between awareness level of metacognitive instructional strategies and the problem-solving skills.

1.7. RESEARCH QUESTIONS

1.7.1. What is the awareness level of metacognitive instructional strategies among secondary stage students before and after the intervention of independent variable?

1.7.2. What is the difference between the mean score of problem-solving skills between students taught through metacognitive instructional strategies and those taught through traditional method of teaching?

1.7.3. What is the correlation between awareness level of metacognitive instructional strategies and the problem-solving skills?

1.8. HYPOTHESES

1.8.1. **H_0:** There is no significant difference in the mean scores of problem-solving skills between students taught through metacognitive instructional strategies and those taught through traditional teaching methods.

1.8.2. **H_1:** There is a significant difference in the mean scores of problem-solving skills between students taught through metacognitive instructional strategies and those taught through traditional teaching methods.

1.8.3. **H2:** There is a positive correlation between awareness level of metacognitive instructional strategies and problem-solving skills

CHAPTER 2

REVIEW OF THE RELATED LITERATURE

2. REVIEW OF RELATED LITERATURE

2.1. FOUNDATIONAL CONCEPTS OF METACOGNITION

Flavell (1979) first articulated the idea of *metacognition* as individuals' knowledge about and regulation of their own thinking. He proposed that learners who deliberately plan, monitor, and evaluate their cognition can develop greater control over learning tasks. His foundational framework introduced the dual components of metacognitive knowledge and metacognitive regulation. This early conceptualisation has since informed decades of research on learning strategies, forming the cornerstone for understanding how learners become independent problem solvers.

Wang, Haertel and Walberg (1990) analysed a wide range of educational research and concluded that classroom practices which foster metacognitive self-regulation are among the strongest predictors of student success. Their content analysis suggested that learners who are taught to think about their learning, adjust their strategies, and evaluate outcomes develop stronger academic performance, including improved problem-solving skills. This study highlighted the importance of intentional instructional design to enhance student thinking.

Alaiyemola, Jegede and Okebukola (1990) conducted an experimental study with Nigerian secondary science students and found that the use of metacognitive strategies helped reduce academic anxiety and improve conceptual understanding. Students exposed to guided planning and reflective thinking performed better on science tasks. Their work established an important link between emotional well-being and cognitive development, illustrating that metacognitive support not only improves learning but also supports learner confidence.

Schraw and Dennison (1994) developed the Metacognitive Awareness Inventory (MAI), a widely used tool to assess student awareness across five domains: planning, information management, monitoring, debugging, and evaluation. They confirmed that these dimensions jointly predict a student's ability to approach new or unfamiliar problems successfully. Their model has since guided instructional research and classroom practice in building reflective learners.

Schraw and Moshman (1995) proposed a theoretical model that categorized learners' metacognitive theories as tacit, informal, or formal. They argued that students develop deeper learning strategies when educators explicitly engage them in thinking about their thinking. By encouraging learners to reflect, educators can support progression toward more structured and effective problem-solving approaches. This work remains relevant for shaping instructional interventions that promote learner autonomy.

2.2. EARLY EMPIRICAL EVIDENCE

Maqsud (1998) implemented metacognitive instructional techniques among low-achieving mathematics students and reported significant gains in both academic achievement and learner attitude. The quasi-experimental design revealed that students who received training in goal-setting, progress monitoring, and strategy evaluation performed substantially better than their peers. This study underlined the accessibility of metacognitive strategies for struggling learners and their potential to foster mathematical problem-solving competence.

Zimmerman (2002) synthesised research on self-regulated learning and proposed a cyclical model encompassing three phases: forethought, performance, and self-reflection. Each phase is underpinned by metacognitive awareness. According to his model, successful problem solvers actively plan strategies, monitor their implementation, and reflect on outcomes to adjust future approaches. Zimmerman's framework offers valuable insight into how learners sustain motivation and adapt to challenges in academic tasks.

National Council of Educational Research and Training (2005) formally advocated for the development of metacognitive abilities in its *National Curriculum Framework*. It recommended that schools promote "learning how to learn" by embedding reflective and self-directed learning practices across subjects, including science. This national policy shifted the focus of Indian pedagogy from content delivery to competency-based learning, reinforcing the importance of fostering metacognitive thinking at the secondary level.

Annevirta and Vauras (2006) conducted a longitudinal study tracking students from elementary through lower secondary school. They found that metacognitive skills develop gradually but can be accelerated through deliberate instruction. Students who received structured support in planning, questioning, and monitoring improved their ability to organize information and solve complex academic problems. This work confirmed the importance of scaffolding metacognitive development over time.

Veenman, Van Hout-Wolters and Afflerbach (2006) highlighted the methodological complexity of studying metacognition and argued for using multiple data sources—

including verbal protocols, self-reports, and performance metrics—to fully understand how learners regulate their cognition. Their work provided researchers and educators with a stronger foundation for assessing and improving students' metacognitive behaviours in real-world problem-solving contexts.

2.3. INSTRUCTIONAL TECHNIQUES AND MEASUREMENT

McKeown and Gentilucci (2007) introduced the Think-Aloud strategy in middle school second-language classrooms to examine its effects on metacognitive development and comprehension. Their study found that students trained to verbalize their thinking processes became more adept at monitoring their understanding and correcting misunderstandings during reading tasks. The implications of their work extend beyond literacy, as verbalized reasoning is also central to effective scientific and mathematical problem-solving. Their findings suggest that encouraging learners to articulate thought processes aloud helps internalize self-regulatory behaviours essential for academic success.

Dignath and Büttner (2008) conducted a meta-analysis involving primary and secondary school interventions to identify key components of successful self-regulated learning programmes. Their research concluded that explicitly teaching students how to plan, monitor, and evaluate their learning significantly improved academic outcomes. They observed that students who received metacognitive instruction demonstrated stronger strategic awareness and problem-solving proficiency, validating the importance of structured strategy instruction at all stages of schooling. The study provides foundational evidence that supports the incorporation of metacognitive practices into core instructional frameworks.

Trilling and Fadel (2009), in their work on 21st-century skills, identified metacognition as a crucial competence for lifelong learning. They argued that reflective learners who possess the capacity to evaluate their thinking, adapt their strategies, and transfer knowledge across contexts are more prepared for modern challenges. Their analysis emphasized that metacognitive awareness enhances adaptability and problem-solving, both of which are critical for navigating complex academic and real-world scenarios. The inclusion of metacognitive thinking in educational priorities is central to fostering learners who are self-directed and capable of managing uncertainty.

Zohar and Dori (2011) explored the role of metacognition in science education through a detailed analysis of instructional strategies. They emphasized the importance of embedding reflective activities within inquiry-based learning environments. According to their findings, students who engaged in metacognitive practices—such as planning investigations, analyzing outcomes, and revising hypotheses—demonstrated enhanced scientific reasoning and conceptual clarity. Their study confirmed that metacognitive scaffolding empowers learners to navigate the complexities of scientific problem-solving more effectively and independently.

2.4. CREATIVE AND DOMAIN-SPECIFIC EXPANSION

Fleming and Lau (2014) examined various approaches to measuring metacognition and underscored the significance of developing accurate assessment tools to evaluate metacognitive processes. They proposed using confidence-accuracy correlations, judgments of learning, and post-task reflection to capture learners' self-evaluation capabilities. These tools provide insights into how effectively students monitor their performance, which is critical for addressing errors and improving outcomes in problem-solving tasks. Their contribution is particularly important for educational researchers and practitioners seeking to evaluate the impact of instructional interventions on student cognition.

Hargrove and Nietfeld (2014) investigated how metacognitive instruction influences students' creative problem-solving capabilities. Through a controlled experimental design, they demonstrated that learners exposed to reflective strategy training developed more original and flexible approaches to solving open-ended problems. The findings highlighted that metacognition is not only essential for academic success but also plays a significant role in fostering creativity and innovation. By cultivating awareness of one's thinking processes, students can navigate complex and ambiguous problems with greater resourcefulness and confidence.

Murray (2014) implemented a case study using color-coded drafts to foster higher-order thinking and metacognitive awareness among first-year college students. His approach encouraged students to visually track their revisions and reflect on their learning journey. This iterative writing process cultivated critical reflection, enabling students to recognize patterns of error, question assumptions, and refine their problem-solving strategies. Murray's findings support the integration of reflective activities into coursework to develop metacognitive thinking in both humanities and STEM domains.

Bruckermann, Aschermann, Bresges, and Schlüter (2017) evaluated the effectiveness of combining multimedia experiments with metacognitive support in science teacher preparation programmes. Their study revealed that preservice teachers who received both forms of scaffolding displayed higher proficiency in planning experiments, identifying variables, and interpreting results. These skills are vital for scientific inquiry and underscore the importance of metacognitive prompts in improving future educators' instructional competence. The research also supports using technology-enhanced tools to build metacognitive capacities in learners.

2.5. POLICY ALIGNMENT AND GLOBAL PERSPECTIVE

Organisation for Economic Co-operation and Development (2018) introduced the OECD Learning Compass 2030 to provide a framework for the future of education. The framework places metacognitive competencies at the centre of student agency, highlighting the need for learners to navigate their own learning paths by setting goals, reflecting on outcomes, and adapting strategies. These abilities are seen as essential not only for academic success but also for lifelong learning and citizenship in a rapidly evolving world. The emphasis on metacognition within the OECD's vision underscores its growing importance in global education policies aimed at equipping students with the tools needed for complex problem-solving.

Rhodes (2019) conducted a comprehensive review of literature on the instructional applications of metacognition and its impact on academic achievement. His work concluded that teaching students to explain their reasoning and evaluate their learning processes significantly improves their ability to perform complex tasks. He emphasized the importance of instructional strategies that engage students in self-questioning, feedback interpretation, and error correction. These metacognitive habits enhance learners' ability to monitor their problem-solving approaches, making them more flexible and accurate in applying their knowledge.

Ministry of Education (2020), through India's National Education Policy (NEP) 2020, underscored the importance of competency-based education and reflective thinking. The policy highlighted the integration of metacognitive strategies such as project-based learning, peer assessment, and formative evaluation in mainstream classroom practice. NEP 2020 emphasizes student-centred pedagogy and encourages teaching methods that foster critical thinking, problem-solving, and self-directed learning. The incorporation of metacognitive practices into national policy signifies a strategic shift in how Indian education aims to develop independent, adaptable learners equipped for 21st-century challenges.

Hancock and Karakok (2020) focused on supporting the development of process-focused metacognition in mathematical problem-solving. Their findings revealed that when students were guided to reflect not only on the solutions but also on the process they followed, their understanding of mathematical concepts deepened. This reflective approach helped students identify more effective strategies and develop persistence in solving challenging problems. The research supports instructional methods that encourage students to monitor their thinking continuously throughout problem-solving activities.

Mohseni, Seifoori, and Ahangari (2020) investigated the impact of metacognitive strategy instruction alongside critical thinking development in reading comprehension among secondary students. Their quasi-experimental study demonstrated that students who received metacognitive training showed significant gains in reading comprehension, analytical skills, and cognitive flexibility. The results support the integration of metacognitive training across subject areas, illustrating how such strategies enhance students' capacity to interpret, evaluate, and solve complex problems.

Muhid, Amalia, Hilaliyah, Budiana, and Wajdi (2020) assessed the effectiveness of implementing metacognitive strategies in secondary reading classes in Indonesia. The study employed a pre-test/post-test design and found that students who practiced techniques such as self-questioning and summarization showed notable improvements in comprehension and task performance. The findings reinforced the role of metacognitive instruction in equipping students with the cognitive tools needed for independent learning and effective problem-solving.

Usta and Yılmaz (2020) applied the KWL (Know-Want-Learn) strategy in Grade 4 mathematics classrooms and found that students using the strategy outperformed those in traditional instruction on multi-step problem-solving tasks. The strategy helped students activate prior knowledge, set specific learning goals, and reflect on their learning outcomes, all of which are critical components of metacognitive awareness. Their research emphasizes the early introduction of structured reflective tools to develop strategic thinking skills from a young age.

UNESCO (2020), in its Global Education Monitoring Report, emphasized inclusive education and the importance of metacognitive practices for diverse learners. The report argued that teaching students to regulate their learning processes promotes equity by enabling all students—regardless of background or ability—to become successful problem-solvers. By advocating for learner-centred approaches that support reflection, goal-setting, and strategy evaluation, UNESCO positioned metacognition as a vital component of inclusive and quality education worldwide.

Baral (2021) studied the impact of metacognitive interventions on metacognitive awareness, academic self-efficacy, and achievement among Indian higher secondary school students. The study involved structured metacognitive training sessions, which led to marked improvements in students' self-regulation and confidence in tackling complex academic tasks. Baral's research offers compelling evidence for the positive correlation between metacognitive instruction and both cognitive and affective student outcomes.

Lytra and Drigas (2021) explored the use of metacognitive scaffolds in STEAM education for learners with Specific Learning Disabilities (SLD). Their findings revealed that when students with SLDs engaged in guided metacognitive reflection and goal-setting, they developed greater autonomy, improved performance, and reduced frustration in problem-solving tasks. This work highlights the inclusive potential of metacognitive instruction and its adaptability to varied learning needs.

Stanton, Sebesta, and Dunlosky (2021) synthesised classroom-based interventions and reported that simple strategies—such as student-generated self-tests and structured reflection journals—enhanced both academic performance and metacognitive ability in undergraduate life science courses. The research confirmed that fostering reflection and self-monitoring supports problem-solving even in large classroom settings and across complex content domains.

OECD (2021) reaffirmed the value of metacognition in its follow-up report, Trends Shaping Education. The report reiterated the need for education systems to cultivate learners who can self-regulate, adapt, and solve problems across disciplines. It urged policymakers and educators to integrate metacognitive instruction into curriculum design and classroom practices as part of preparing students for uncertainty and lifelong learning.

2.6. TEACHER DEVELOPMENT AND ASSESSMENT INNOVATION

De Vries, Dimosthenous, Schildkamp, and Visscher (2022) examined the role of teacher professional development in promoting student metacognition through an Assessment for Learning (AfL) program. Their findings demonstrated that when teachers engaged in ongoing training focused on formative feedback, learning goal clarity, and student self-assessment, students displayed significant improvement in their ability to monitor and regulate their learning. The program encouraged teachers to use reflective questioning techniques and facilitate discussions about learning strategies, enabling students to become more strategic and thoughtful in problem-solving situations. This study confirms the vital connection between teacher training and the cultivation of metacognitive skills in learners.

Elbyaly and Elfeky (2022) investigated the impact of metacognitive training in online learning environments, particularly during the COVID-19 pandemic when many students participated in Massive Open Online Courses (MOOCs). Their study revealed that metacognitive scaffolds—such as reflection prompts and progress-tracking dashboards—significantly enhanced learners' ability to process information deeply and apply knowledge across contexts. Students who engaged in self-monitoring activities outperformed those in traditional online courses on complex analytical tasks, highlighting the importance of intentional strategy instruction in virtual education settings. This research supports the growing integration of metacognitive strategies into digital learning platforms.

Bagga and McKee (2023) explored the application of metacognitive instruction in oral health education, drawing attention to its potential in clinical reasoning and professional development. The researchers noted that students trained in self-assessment and reflective inquiry exhibited stronger diagnostic skills and decision-making capabilities. While their study was based in medical education, the findings have direct relevance to secondary science instruction, where problem-solving requires careful analysis and evidence-based reasoning. Their work reinforces the value of metacognitive strategies in enhancing applied learning and professional competencies.

Rajadurai and Ganapathy (2023) focused on the use of metacognitive instructional strategies among undergraduate students preparing for competitive mathematics examinations. Their quasi-experimental study found that students who were explicitly trained in planning, monitoring, and evaluating their mathematical problem-solving approaches showed marked improvement in performance. These learners also demonstrated greater persistence and flexibility in tackling complex problems. The findings emphasize the transferability of metacognitive instruction across educational stages and confirm its effectiveness in high-stakes academic environments.

Wass et al. (2023) examined the influence of pedagogical training on the development of students' metacognitive skills in diverse classroom settings. Their study highlighted the importance of teachers modeling reflective thinking and providing explicit instruction in metacognitive strategies. Teachers who practiced self-reflection and shared their problem-solving approaches fostered a classroom culture where students felt empowered to think critically and independently. The study concluded that metacognitively aware educators are better positioned to guide learners toward strategic thinking and effective problem-solving.

Taguma, Makowiecki, and Gabriel (2023) analyzed the implications of the OECD Learning Compass 2030 for mathematics curricula and proposed the inclusion of metacognitive checkpoints throughout instructional sequences. These checkpoints help students assess their understanding, adjust strategies, and plan next steps. The authors argued that embedding metacognitive processes into mathematics education ensures that learners become not just proficient in content, but also capable of solving novel and complex problems. Their research reinforces the need for curriculum developers to integrate reflection and self-regulation into subject-specific frameworks.

2.7. CONTEMPORARY EMPIRICAL EXTENSIONS

Das, Khatun, Mohakud, and Khan (2024) examined the role of self-directed learning in the context of India's NEP 2020 and its impact on student engagement and problem-solving. Their findings indicated that when students engaged in metacognitive planning, such as setting personal learning goals, tracking their progress, and adjusting strategies, they demonstrated higher levels of motivation, curiosity, and academic performance. The study supports the view that metacognition is a critical component of 21st-century learning, enabling students to thrive in flexible, learner-centred environments.

Danlami, Ginga, Aliyu, Umahaba, and Tsoho (2024) conducted a quasi-experimental study on the effectiveness of the KWL (Know–Want–Learn) strategy in improving geometry problem-solving among Upper Basic students in Nigeria. The results showed that students who used the KWL chart outperformed their peers in conceptual understanding and spatial reasoning. The strategy allowed learners to activate prior knowledge, identify learning objectives, and reflect on their progress, thus fostering metacognitive engagement.

The study affirms the utility of structured metacognitive tools in promoting problem-solving competence.

Toikka, Eronen, Atjonen, and Havu-Nuutinen (2024) explored students' metacognitive knowledge and its relationship to mathematical problem-solving. Their research integrated the dimensions of declarative, procedural, and conditional knowledge, demonstrating that students who possessed a comprehensive understanding of how, when, and why to apply problem-solving strategies achieved significantly higher scores. This study reinforces the idea that metacognitive instruction must address all facets of strategic knowledge to build robust problem-solving skills in mathematics.

2.8. CONCLUSION

The review of literature from 1979 to 2024 offers compelling evidence that metacognitive instructional strategies significantly enhance students' ability to solve problems, particularly in mathematics and science education. Researchers consistently affirm that when students are explicitly taught how to plan, monitor, and evaluate their thinking, they become more effective, reflective, and independent learners. Metacognitive instruction not only improves academic performance but also supports emotional resilience, motivation, and adaptability—skills that are essential for success in the modern world.

In addition, national and international educational policies, including India's NEP 2020 and the OECD Learning Compass 2030, strongly advocate the integration of metacognitive practices into mainstream curricula. These policies align with the empirical research emphasizing the role of self-regulation in developing 21st-century competencies. However, despite the extensive body of global literature, there remains a need for more context-specific studies in Indian secondary schools, particularly using quasi-experimental methods to evaluate the impact of metacognitive strategies on domain-specific problem-solving.

In light of these insights, the present study seeks to address these gaps by investigating the effect of metacognitive instructional strategies on promoting problem-solving skills among secondary stage students. The study aims to contribute to the growing field of metacognitive research and provide practical implications for enhancing teaching and learning in Indian classrooms.

CHAPTER-3

RESEARCH METHODOLOGY

3. RESEARCH METHODOLOGY

3.1. INTRODUCTION:

This chapter describes the methodology adopted to examine the effectiveness of metacognitive instructional strategies in promoting problem-solving skills among secondary stage students. It includes the research design, variables, population and sample, intervention details, data collection procedures, tools, and statistical techniques used.

3.2. RESEARCH DESIGN

A non-equivalent pre-test–post-test control group design, drawn from a quasi-experimental research methodology, was employed to compare the effects of metacognitive instructional strategies with traditional teaching methods on secondary students' problem-solving skills. The design was selected because the study involved intact classes where complete randomization of individual students was not feasible. Two intact sections of class X were randomly assigned—one to the experimental condition and one to the control condition (Nworgu, 2015). The experimental class received metacognitive instructional strategies (such as guided self-questioning, planning-monitoring-evaluation prompts, and reflective think-aloud modelling) during their science problem-solving lessons, whereas the control class was taught through traditional teaching method, content-centred teaching. Both groups were assessed through an identical problem-solving assessment before (pre-test) and after (post-test) the intervention, allowing for a direct comparison of learning gains attributable to the metacognitive instructional approach.

3.3. CONCEPTUAL FRAMEWORK

The present study aims to examine the effect of metacognitive instructional strategies in promoting problem-solving skills among secondary stage students. Figure 3.1 illustrates the conceptual framework that guides this investigation. The research adopts a quasi-experimental design involving two groups: an experimental group and a control group. Initially, both groups undergo a pre-test to assess their existing levels of problem-solving skills. Following this, the experimental group taught using metacognitive instructional strategies, which include planning, monitoring, and evaluation techniques, while the control group is taught using traditional methods of instruction. After the instructional intervention, both groups are administered a post-test to measure any changes in their problem-solving performance. This framework allows for a comparison of data obtained in the pre-test and post-test scores within each group to determine to determine the effect of the intervention. By assessing differences in performance, the study seeks to determine whether metacognition instructional strategies lead to enhanced problem-solving abilities in comparison to traditional instructional approaches. This comparative analysis offers valuable insights into the role of metacognitive instructional strategies in secondary education.

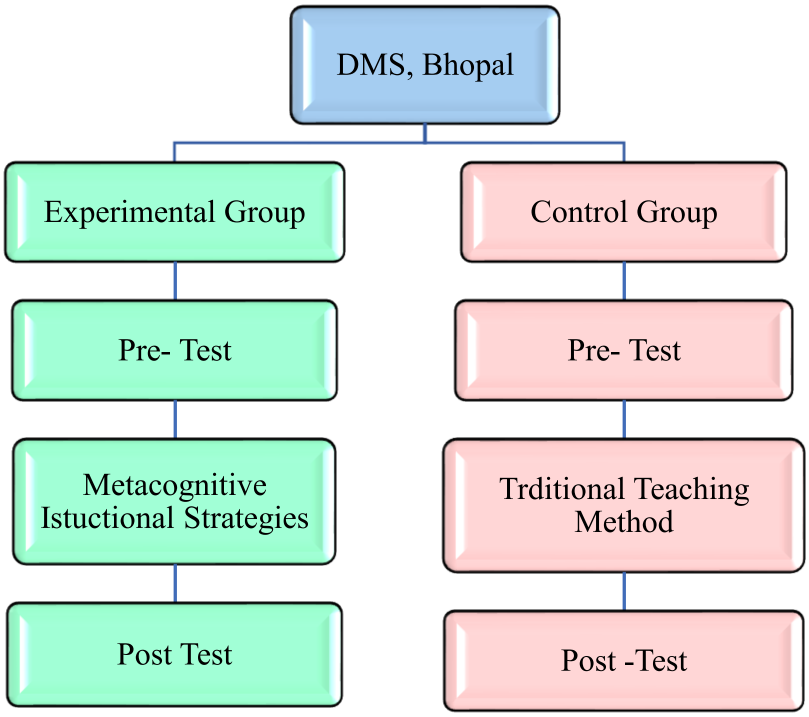

Fig. 3.1. Conceptual Framework of the research

3.4. POPULATION AND SAMPLE

Population: The population for this study consists of **Class X** students enrolled in CBSE-affiliated schools in Bhopal, Madhya Pradesh.

Sample: The sample consisted of 60 students (30 in each group) selected from **Demonstration Multipurpose School (DMS), Bhopal**. For the purpose of the study, two sections from the school were selected using the simple random sampling technique. One section was assigned as the experimental group and was taught through metacognitive instructional strategies, while the other section served as the control group and was taught through the traditional teaching method. The selection was based on administrative feasibility and ensured comparability in student profiles.

Sampling Technique: Simple random sampling was used to assign one section each to experimental and control groups.

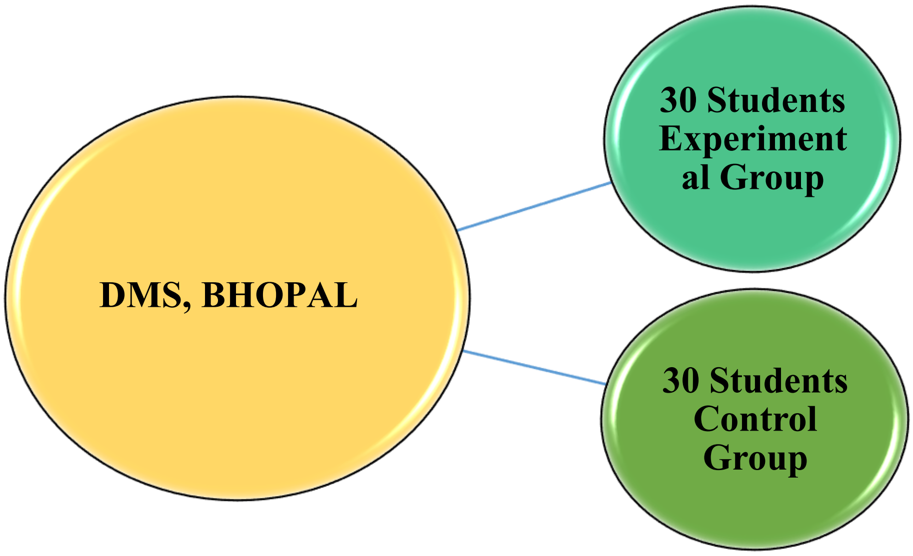

Fig.3.2. Number of students in Experimental and Control Group.

3.5. VARIABLES

The present study involved two main types of variables.

The **independent variable** was the use of **metacognitive instructional strategies**, which was applied to the experimental group. These strategies were designed to actively engage students in the learning process by encouraging reflection, self-regulation, and strategic thinking.

The **dependent variable** was the **problem-solving skills of students in Biology**, which were assessed to determine the effectiveness of the metacognitive instructional strategies. The study aimed to explore how the implementation of the independent variable influenced the dependent variable among secondary stage students.

3.6. DATA COLLECTION PROCEDURE

The data collection procedure was systematically carried out in three stages over a 20-day intervention period, ensuring structured implementation and uniformity across both experimental and control groups.

Stage 1: Pre-Test Administration

In the beginning of the study, both the experimental and control groups were administered. A Biology Pre-Test to assess their baseline levels of problem-solving skills. Additionally, the Metacognitive Awareness Inventory (MAI) was administered to both groups to evaluate their initial metacognitive awareness level.

Stage 2: Instructional Intervention

During the intervention phase, the experimental group was taught Biology through metacognitive instructional strategies. These strategies emphasized key components such as planning, cognitive monitoring, and self-evaluation, integrated within the instructional content. In contrast, the control group was instructed through traditional, teacher-centered methods that did not incorporate metacognitive prompts or reflective activities. Both groups were exposed to the same Biology syllabus content to ensure consistency in subject matter across instructional methods.

Stage 3: Post-Test Administration

At the conclusion of the 20-day intervention period, both groups were administered the Biology Post-Test to assess their problem-solving skills after instruction. The Metacognitive Awareness Inventory (MAI) was also re-administered to measure any changes in metacognitive awareness level. This structured and sequential data collection procedure enabled a clear and reliable comparison of both problem-solving performance and metacognitive instructional strategies between the two groups.

3.7. TOOLS AND TECHNIQUES

To collect valid and reliable data for the study, two key tools were used. These tools were designed to assess both cognitive (problem-solving) and metacognitive (awareness and regulation) domains of learning. The tools were administered to both the experimental and control groups before and after the intervention to evaluate changes attributed to the metacognitive instructional strategies.

3.7.1. Biology Pre-Test and Post-Test Questionnaire

This assessment tool was specifically developed in accordance with the Class X CBSE Biology syllabus, particularly focusing on the chapters “Photosynthesis” and “Respiration.” It aimed to assess students’ conceptual understanding, application skills, and problem-solving skills.

Structure and Features:

- The test consisted of multiple-choice questions (MCQs) that assessed knowledge, comprehension, application, and analysis.
- Items were constructed using Bloom's Revised Taxonomy to ensure a mix of lower and higher-order thinking skills.
- The test was reviewed and validated by subject matter experts in science education to ensure content and construct validity.
- It was used as a pre-test to assess baseline performance and as a post-test to evaluate the effect of the intervention.

Scoring: Each correct response was awarded one mark. There was no negative marking. The data were analyzed using descriptive, and inferential statistical techniques.

3.7.2. Metacognitive Awareness Inventory (MAI)

The Metacognitive Awareness Inventory was employed to assess students' metacognitive awareness level and their ability to regulate their learning processes. For the purpose of this study, the original MAI was adapted to suit the language and comprehension level of secondary stage school students.

Structure and Features:

- The adapted version consisted of 30 Yes/No items grouped under four key domains:
    - Knowledge of Cognition
    - Regulation of Cognition
    - Problem-Solving Awareness
    - Strategy Awareness and Use
- The inventory captured students' understanding of their cognitive strengths and weaknesses, as well as their use of planning, monitoring, and evaluation strategies.
- It served as both a pre-test and post-test to track growth in metacognitive awareness.

Scoring: A score of 1 was assigned to each "Yes" response and 0 to each "No" response. The total score out of 30 represented the student's level of metacognitive awareness. Data were analyzed using independent samples t-tests and Pearson's correlation coefficient to explore relationships with problem-solving performance.

Table No. 3.1. Description of Research Tools Used for Data Collection

Tool	Purpose	Format	Area Assessed	Scoring Method	Use
Biology Problem-Solving Test	Assess understanding and problem-solving skills	Multiple Choice	Biology: Photosynthesis & Respiration	2 mark per correct answer	Pre-Test & Post-Test
Metacognitive Awareness Inventory (MAI)	Evaluate awareness and regulation of cognition	Yes/No	Metacognitive knowledge and regulation	1 for Yes, 0 for No	Pre-Test & Post-Test

3.8. STATISTICAL TECHNIQUES USED:

Both descriptive and inferential statistical techniques were employed to analyse the collected data. Descriptive statistics, including the mean and standard deviation, provided a summary of the performance distribution of pre-test and post-test scores for the experimental group (taught with metacognitive strategies) and the control group (taught with traditional methods). Inferential statistics involved the use of the independent sample t-test to assess the significance of any differences between group means at a 0.05 significance level. Additionally, Pearson's correlation coefficient was computed to examine the relationship between students' pre-test and post-test scores, providing insight to understand individual learning improvement and the overall effect of metacognitive instructional strategies on problem-solving skills.

- **Descriptive statistics:** Mean and Standard Deviation
- **Inferential statistics:** Independent Samples t-test, Pearson's Correlation Coefficient

CHAPTER-4

DATA ANALYSIS AND INTERPRETATION

4. DATA ANALYSIS AND INTERPRETATION

4.1. INTRODUCTION

This chapter presents the analysis and interpretation of data collected for the study titled, *"A Study on the Effect of Metacognitive Instructional Strategy in Promoting Problem-Solving Skills among Secondary Stage Students."* The study adopted a quasi-experimental design with a control and an experimental group, each comprising 30 students.

The purpose of this chapter is to systematically analyze the data to determine the effectiveness of metacognitive instructional strategies in improving students' problem-solving skills and metacognitive awareness using appropriate statistical techniques.

4.2. ORGANIZATION OF THE DATA

The data were organized according to the two key assessment tools used:

- A Biology Problem-Solving Test (Pre-test and Post-test)
- The Metacognitive Awareness Inventory (MAI) (Pre-test and Post-test)

Each tool was administered to both the experimental and control groups before and after the intervention. The data have been presented in tabular form with corresponding statistical interpretations.

4.3. OBJECTIVE-WISE ANALYSIS, INTERPRETATION AND DISCUSSION OF RESULTS

4.3.1. Objective 1: To assess the awareness level of Metacognitive Instructional Strategies among secondary stage students before and after the intervention of the independent variable.

Analysis Method: A qualitative analysis was conducted using bar graphs to visualize the pre-test and post-test Metacognitive Awareness Inventory (MAI) scores of both the experimental and control groups.

Findings: The experimental group showed a marked increase in MAI scores from M = 14.00 (pre-test) to M = 22.00 (post-test) while the control group scores increased slightly from M= 14.07 (pre-test) to M = 15.03 (post-test).

Table 4.1. Mean Scores of Metacognitive Awareness Inventory (MAI) in Pre-test and Post-test for Experimental and Control Groups

Group	MAI Test	N	Mean
Experimental Group	Pre-Test	30	14
	Post-Test	30	22
Control Group	Pre-Test	30	14.07
	Post-Test	30	15.03

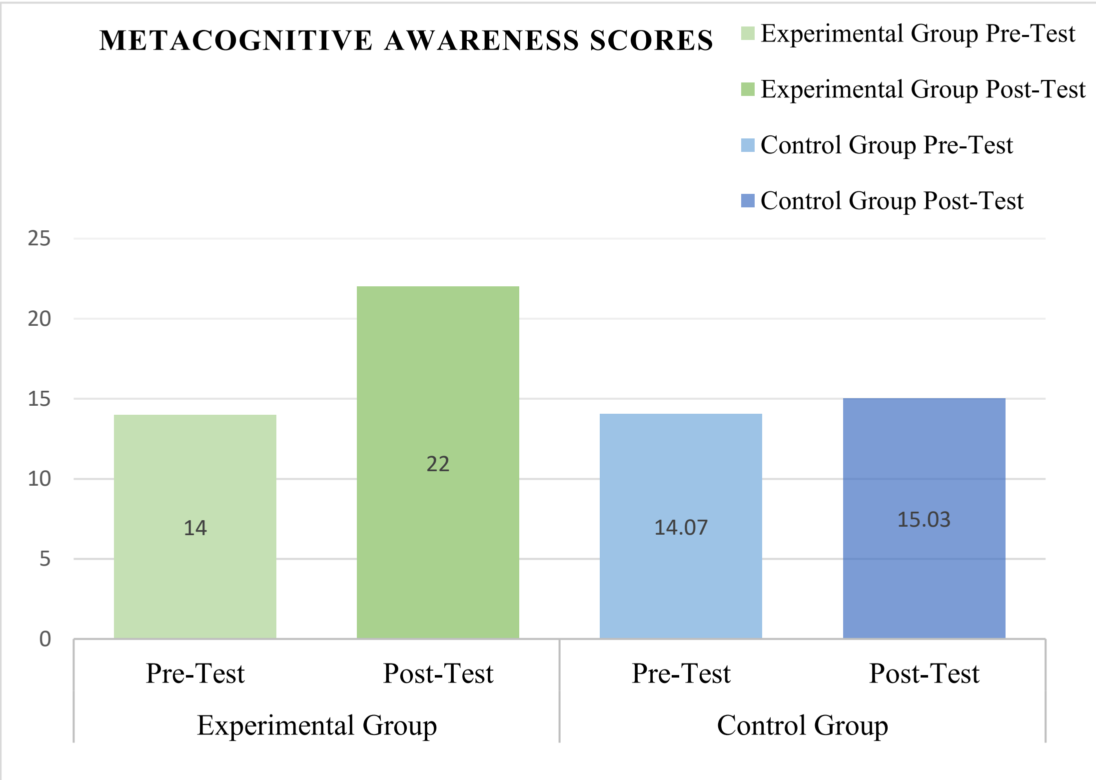

***Figure 4.1.**: Bar Graph Showing Pre-test and Post-test Metacognitive Awareness Scores of Experimental and Control Groups*

Interpretation: There was a clear and meaningful increase in the metacognitive awareness of students who were exposed to metacognitive instructional strategies. In contrast, the control group exhibited only a minimal change in their MAI scores. This suggests that the intervention significantly enhanced students' metacognitive self-awareness and self-regulation skills.

4.3.2. Objective 2: To compare the difference between the mean scores of problem-solving skills between students taught through metacognitive instructional strategies and those taught through traditional teaching methods.

H_0: There is no significant difference in the mean scores of problem-solving skills between students taught through metacognitive instructional strategies and those taught through traditional teaching methods.

H_1: There is a significant difference in the mean scores of problem-solving skills between students taught through metacognitive instructional strategies and those taught through traditional teaching methods.

Analysis Method: An Independent Samples two-tailed t-test was conducted on post-test Biology scores at a significance level of 0.05.

Table 4.2: Independent t-test Results Comparing Post-Test MAI Scores between Experimental and Control Groups

Group	N	Mean	SD	Df	t-value	Critical t- value	Remarks
Experimental Post-Test	30	27	0.74	58	13.81	2.002	Significant
Control Post-Test	30	21.93	1.87				

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

$\bar{x}_1$ = Mean of Experimental Group

$\bar{x}_2$ = Mean of Control Group

S_1 = Standard Deviation of Experimental Group

S_2 = Standard Deviation of Control Group

$n_1 = n_2 = 30$

$$\boldsymbol{t} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{27-21.93}{\sqrt{\frac{0.74^2}{30} + \frac{1.87^2}{30}}} = \frac{5.07}{\sqrt{0.0183+0.1166}} = \frac{5.07}{\sqrt{0.1349}} = \frac{5.07}{0.3673} \approx \mathbf{13.81}$$

Degrees of Freedom (Df): Df = n_1+n_2-2 = 30+30-2 = 58

The calculated t-value is 13.81. At a significance level of 0.05 (α=0.05) and degrees of freedom (Df = 58), the critical t-value (two-tailed) is approximately 2.002.

Since the calculated t-value (13.81) is much greater than the critical t-value (2.002), at the 0.05 significance level (two-tailed) with the 58 degrees of freedom, the difference in means is statistically highly significant and therefore, the null hypothesis is rejected.

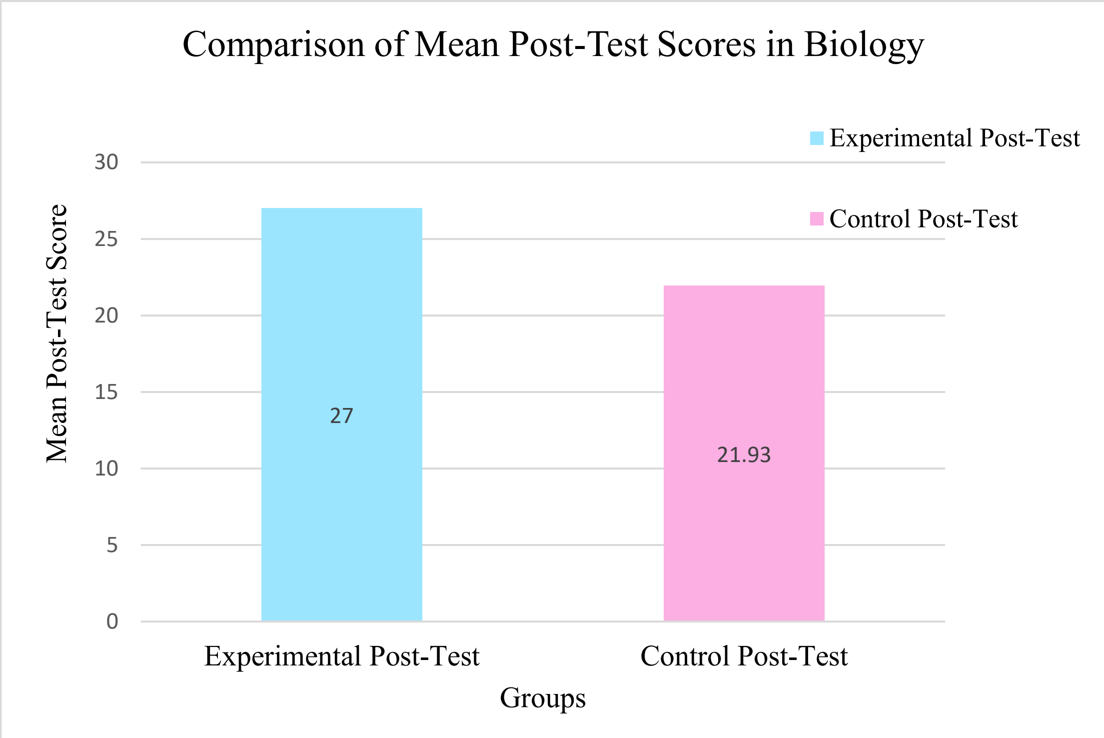

Figure 4.2.: *Bar graph showing the mean post-test scores in Biology for the experimental group (M = 27.00, SD = 0.74) and the control group (M = 21.93, SD = 1.87). The experimental group was taught using metacognitive instructional strategies, while the control group received traditional instruction. Error bars represent standard deviation. The significant difference between groups (t = 13.81, p < 0.05) indicates a positive impact of metacognitive strategies on students' problem-solving skills.*

Interpretation: There is a significant difference between the post-test scores of Biology of students taught through metacognitive instructional strategies (experimental group) and those taught through traditional methods (control group). This indicates that the use of metacognitive instructional strategies had a positive impact on students' learning outcomes and problem-solving skills.

4.3.3. Objective 3: To study the correlation between awareness level of metacognitive instructional strategies and the problem-solving skills.

H_2: There is a positive correlation between awareness level of metacognitive instructional strategies and the problem-solving skills.

Analysis Method: To examine the relationship between students' metacognitive awareness and their problem-solving performance, the Pearson correlation coefficient (r) was calculated.

In this study, Pearson's r was computed using the MAI post-test scores (representing metacognitive awareness) and the Biology post-test scores (representing problem-solving skills) of students from the experimental group.

Table 4.3 Pearson Correlation Coefficients between MAI Post-Test & Biology Post-Test Scores

Group	Score Comparison	r	Strength of Relationship	Interpretation
Experimental	MAI vs. Biology post-test	**0.94**	Strong positive association	Students with higher metacognitive awareness tended to achieve higher Biology scores.
Control	MAI vs. Biology post-test	**0.11**	Very weak relationship	Minimal association between awareness and Biology scores; changes likely due to uncontrolled factors.

Note: r = Pearson correlation coefficient; critical r at $p < 0.01$ (two-tailed, df = 28) ≈ 0.463.

Interpretation: Pearson's correlation analysis was conducted to determine the linear relationship between students' metacognitive awareness (MAI post-test scores) and their problem-solving performance in Biology (post-test scores).

- **Experimental group:** The analysis produced an r-value of 0.94 ($p < 0.01$), indicating a strong, statistically significant positive correlation. This result confirms that students who developed higher levels of metacognitive awareness after explicit strategy instruction were also the ones who achieved the highest scores on the Biology problem-solving test. In practical terms, the intervention through metacognitive instructional strategies not only raised average performance but also aligned individual gains in awareness with corresponding gains in problem-solving skills.

- **Control group:** In contrast, the control group yielded an r -value of 0.11, which represents a very weak and non-significant relationship between MAI scores and Biology achievement. This minimal association suggests that, without targeted metacognitive instruction, improvements in Biology performance were largely independent of students' self-reported awareness levels and may have been influenced by random variation or uncontrolled classroom factors.

Overall, these findings support Hypothesis H_2 and underscore the critical role of metacognitive instructional strategies in enhancing students' capacity to regulate their thinking and apply effective problem-solving skills in science learning contexts.

CHAPTER- 5

SUMMARY, FINDINGS, SUGGESTIONS, AND CONCLUSION

5. FINDINGS, IMPLICATIONS, SUGGESTIONS AND CONCLUSION

5.1. INTRODUCTION

This chapter provides a concise synthesis and critical evaluation of the study's key findings. It also explores the identified limitations and outlines directions for future research. The summarized results focus on the effectiveness of metacognitive instructional strategies in promoting problem solving skills.

5.2. MAJOR FINDINGS OF THE STUDY

This section presents a summary of the results drawn after the analysis and interpretation of the data. This research study examines the effectiveness of metacognitive instructional strategies among secondary stage students. The research specifically considered fourth-grade Mathematics curriculum. The research specifically considered secondary stage students and Problem-solving skills with respect to metacognitive instructional strategies.

- **Improvement in Metacognitive Awareness:** The results of the Metacognitive Awareness Inventory (MAI) revealed a notable improvement in the metacognitive awareness of students who received metacognitive instructional strategies. Specifically, the experimental group had a mean pre-test score of 14.00, which increased significantly to 22.00 in the post-test after the intervention. In contrast, the control group, which was taught through traditional instructional methods, showed only a marginal improvement, with the mean score increasing from 14.07 in the pre-test to 15.03 in the post-test. These results suggest that explicit instruction in metacognitive strategies substantially enhances students' ability to be aware of and regulate their own learning processes. The minimal change observed in the control group further reinforces the effectiveness of metacognitive instruction in fostering self-awareness and strategic thinking among secondary stage students.

- **Enhanced Problem-Solving Skills in Biology:** The post-test results in Biology demonstrated a significant improvement in the problem-solving skills of students who were taught using metacognitive instructional strategies. The experimental group (N = 30) achieved a mean post-test score of 27.00 with a standard deviation of 0.74, while the control group, which received conventional instruction, recorded considerably lower scores (not shown here but comparatively less effective). An independent samples t-test was conducted to assess the significance of this difference. The calculated t-value was 13.81, which far exceeds the critical t-value of 2.002 at 58 degrees of freedom and the 0.05 significance level. This statistically significant result confirms that the use of metacognitive strategies leads to enhanced academic achievement and more effective problem-solving in science, particularly in the domain of Biology.

- **Positive Correlation between Metacognitive Awareness and Problem-Solving:** The findings of the present study reveal a strong and statistically significant positive correlation ($r = 0.94$, $p < 0.01$) between students' metacognitive awareness and their problem-solving performance in Biology within the experimental group. This suggests that students who developed higher levels of metacognitive awareness through explicit strategy instruction were also more successful in solving biology-based problems. In other words, enhanced metacognitive skills—such as planning, monitoring, and evaluating one's thinking—appeared to directly contribute to improved academic performance in problem-solving contexts. This finding underscores the effectiveness of metacognitive instructional strategies not only in raising average achievement levels but also in fostering meaningful cognitive engagement among learners.

  In contrast, the control group exhibited a very weak and statistically non-significant correlation ($r = 0.11$) between metacognitive awareness and Biology performance. This indicates that, in the absence of structured metacognitive intervention, any observed gains in problem-solving were likely incidental and not systematically linked to students' awareness of their cognitive processes. The divergence in these patterns across groups highlights the role of deliberate pedagogical interventions in shaping both metacognitive growth and domain-specific academic skills.

5.3. EDUCATIONAL IMPLICATIONS

A. Implications for Teachers

- **Incorporation of Explicit Metacognitive Strategies**: Teachers are encouraged to embed explicit metacognitive strategies into their daily instructional practices. This includes the use of tools such as reflective journals, planning prompts, exit slips, and progress checklists. These techniques help students become more aware of their thought processes and learning behaviours.

- **Designing Metacognition-Enhancing Activities**: Educators should design learning tasks that promote self-monitoring, goal-setting, strategic thinking, and evaluation. Activities such as "think-aloud" problem-solving, peer discussions, and self-assessment rubrics can significantly enhance metacognitive engagement.

- **Creating a Supportive Learning Environment**: It is essential for teachers to cultivate a classroom culture that encourages student autonomy, inquiry, and reflection. Providing a safe and open space where students can express doubts, make mistakes, and learn from them is critical for developing metacognitive skills.

- **Continuous Professional Development**: Teachers should engage in ongoing professional development programs focusing on metacognitive pedagogy. Workshops and training sessions on instructional design, assessment strategies, and reflective teaching can strengthen their ability to implement such approaches effectively.

B. Implications for Students

- **Development of Self-Regulated Learning Skills**: Students must be encouraged to develop key metacognitive competencies, including planning, monitoring, and evaluating their learning. By consciously applying these skills, students become more strategic and effective learners.
- **Practice of Self-Questioning Techniques**: During problem-solving activities, students should be taught to ask themselves reflective questions such as "What do I already know?", "What strategy can I use?", and "What can I do differently next time?" This habitual self-questioning promotes deeper understanding and critical thinking.

- **Active Engagement in Learning**: The use of metacognitive strategies promotes learner autonomy. Students begin to take ownership of their academic growth by setting personal learning goals, tracking progress, and reflecting on outcomes, thereby becoming self-directed learners.
- **Improvement in Academic Confidence**: As students become more aware of their learning strategies and see improvements in their performance, they build greater confidence and resilience, especially when tackling challenging problems.

C. Implications for Parents

- **Support for Independent Learning at Home**: Parents play a crucial role in reinforcing metacognitive habits outside the classroom. By engaging children in conversations about how they learn and what strategies they use, parents can encourage metacognitive awareness in everyday situations.
- **Encouragement of Curiosity and Problem-Solving**: Parents should foster an environment where curiosity, exploration, and questioning are valued. Encouraging children to reflect on how they solved a problem or approached a task can enhance their analytical and reasoning skills.
- **Creating a Positive and Supportive Atmosphere**: A home environment that celebrates effort, supports reflective thinking, and emphasizes learning from mistakes contributes to the development of a growth mindset. Such an atmosphere enables students to approach academic tasks with a positive attitude and persistence.
- **Collaboration with Educators**: Parents should maintain regular communication with teachers to understand the metacognitive strategies being taught and reinforce them at home. A collaborative home-school partnership is essential for the consistent development of these skills.

5.4. SUGGESTIONS FOR FURTHER STUDY

- **Longitudinal Studies to Assess Sustained Impact**: It is recommended that future research undertake longitudinal investigations to examine the sustained effects of metacognitive instructional strategies on students' academic achievement and learning outcomes over an extended period. Such studies would provide a deeper understanding of the long-term benefits and retention of metacognitive skills.
- **Application Across Various Science Disciplines:** Further research should consider applying metacognitive instructional strategies to other core science

subjects such as Physics, Chemistry, and Mathematics. This would help to evaluate the generalizability and effectiveness of these strategies across different scientific domains.

- **Comparative Research in Diverse Educational Contexts:** Conducting comparative studies between urban and rural schools is recommended to explore how socio-economic and geographical factors influence the implementation and effectiveness of metacognitive teaching methods. These investigations could inform context-sensitive adaptations of instructional strategies.
- **Integration of Digital Tools and Blended Learning Approaches:** Future studies could explore the incorporation of digital tools and blended learning platforms, such as adaptive learning software, online reflective journals, and mobile applications, to enhance the facilitation and monitoring of metacognitive training. This approach may offer innovative ways to engage students and personalize learning in diverse educational settings.

5.5. CONCLUSION

This chapter presents the key findings of the study, synthesizes its conclusions, and outlines its educational implications and recommendations. The findings of the study clearly affirm that metacognitive instructional strategies have a profound and positive impact on the cognitive and metacognitive development of secondary school students, particularly in the context of science education.

When compared with traditional teaching approaches that emphasize rote memorization and passive learning, metacognitive strategies promote deeper engagement with content, foster critical thinking, and enhance self-regulation. Students taught through these strategies demonstrated higher levels of self-awareness, improved independent problem-solving skills, and greater academic achievement, especially in Biology.

Metacognitive instruction not only supports content mastery but also equips learners with essential skills for monitoring, evaluating, and adapting their learning strategies. These reflective and strategic learning approach nurtures students to become inquisitive, autonomous, and resilient, aligning closely with the National Education Policy (NEP) 2020, which calls for the development of holistic, competent, and lifelong learners.

Furthermore, the study makes a significant contribution to the field of self-regulated learning, offering much-needed context-specific insights from an underrepresented region of India. Unlike many studies from Western or urban contexts, this research addresses the challenges of implementing metacognitive strategies in Indian classrooms, such as large class sizes, limited resources, and exam-oriented teaching practices.

The study's implications extend across various levels:

- At the classroom level, teachers are encouraged to integrate simple metacognitive tools like think-alouds, reflection prompts, and goal-setting strategies into their lessons.
- At the institutional level, the research informs teacher training and professional development programs focused on building metacognitive competence.
- At the policy level, it advocates for curriculum reforms and assessment models that prioritize not only content knowledge but also cognitive flexibility and strategic learning skills.

In conclusion, this study demonstrates that embedding metacognitive pedagogy in science classrooms is not only feasible but also transformative. It helps develop a generation of learners who are not only proficient in scientific concepts but also capable of thinking critically, learning independently, and adapting to complex real-world challenges. Thus, the integration of metacognitive instruction represents a crucial step toward fulfilling the vision of NEP 2020 and shaping future-ready learners.

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APPENDIX

PRE-TEST QUESTIONNAIRE (MAI)

Name (Optional): ____

School: ____

Class: __________ **Sec:** ________

Gender: **Male** ____ **Female** ____ **Other** ____

INSTRUCTIONS:

This questionnaire is a part of a research study titled *"A Study on the Effect of Metacognitive Instructional Strategies in Promoting Problem-Solving Skills among Secondary Stage Students."* Your responses will be used strictly for academic and research purposes only.

There are no right or wrong answers. The purpose of this tool is to understand your natural way of thinking and solving problems while learning science concepts. Read each item carefully and select the option that best represents your thoughts or behaviours.

Please keep the following points in mind:

1. **Answer honestly** – Respond according to what you actually think or do, not what you believe is the “right” answer.
2. Read each statement carefully. If you feel the statement applies to you, mark **Yes**. If not, mark **No**.
3. **Do not leave any item unanswered.** If you are unsure, make a thoughtful choice.
4. **All responses will remain confidential** and will be used only for the purpose of this academic study.
5. Try not to overthink your answers. **Go with your first instinct** or the option that feels most natural.

Your cooperation is highly appreciated.

S.NO.	Question	Yes	No
Section A: Knowledge of Cognition			
1.	I am aware of how I learn best.		
2.	I know when I do not understand something.		
3.	I can identify the learning techniques that work for me.		
4.	I understand the goals of my learning tasks.		
5.	I can evaluate how well I have learned something after studying.		
6.	I know which subjects or topics I find easy or difficult.		
7.	I can estimate how much effort I need to learn something new.		
Section B: Regulation of Cognition			
8.	I plan what I will do before starting a learning task.		
9.	I try to focus on what's important while studying.		
10.	I change the way I study if I am not understanding the content.		
11.	I keep checking to see if I am learning correctly while studying.		
12.	I try to understand why I made a mistake in an assignment or test.		
13.	I go back and review things I don't understand.		
14.	I test myself to see if I remember the information.		
15.	I think about how I could do better after completing a task.		
16.	I organize my time before I begin studying.		
17.	I try to link what I am learning with what I already know.		
18.	I think about my learning process while I study.		
19.	I ask myself questions to make sure I understand.		
20.	I try to explain things I have learned in my own words.		

Section C: Problem-Solving Awareness			
21.	When I get stuck on a problem, I try to figure out what went wrong.		
22.	I use different ways to try and solve a problem if the first one doesn't work.		
23.	I think about the steps I should take before I try to solve a science problem.		
24.	I try to understand the meaning of a question before answering it.		
25.	I check my work to see if my answer makes sense.		
Section D: Strategy Awareness and Use			
26.	I choose study methods that help me understand the topic better.		
27.	I try to use examples or diagrams to understand tough concepts.		
28.	I take notes in a way that helps me remember things better.		
29.	I change my strategy when I find something difficult to understand.		
30.	I try to solve questions in steps, not all at once.		

Biology Pre-Test Questionnaire

Name (Optional): ____

School: ____

Class: __________ **Sec:** ________

Gender: **Male** ____ **Female** ____ **Other** ____

Instructions: This questionnaire is a part of a research study titled: **"A Study on the Effect of Metacognitive Instructional Strategies in Promoting Problem-Solving Skills among Secondary Stage Students."**

Your responses will be used strictly for academic and research purposes only. The goal is to understand your current knowledge and thought process related to the biology topic ***Life Processes – Photosynthesis and Respiration.***

Please read the following instructions carefully before beginning the questionnaire:

1. There are a total of **15 questions**, each carrying **2 marks**.
2. The **total marks** for the questionnaire are **30**.
3. **There is no negative marking.**
4. Read each question carefully and select the best possible answer from the options provided.
5. Attempt **all questions**. If you are unsure, choose the answer that seems most appropriate to you.
6. Your responses will be kept **confidential** and will be used only for **research and educational improvement**.
7. Do not overthink your answers—go with your **first instinct**.
8. Take your time and think **critically** about each question. The purpose is to assess not only what you know but also how you apply your understanding to solve problems in science.
9. Your **honest participation** is highly valuable and appreciated.

Thank you for your cooperation.

1. Which gas is essential for photosynthesis?

A) Nitrogen B) Oxygen C) Carbon dioxide D) Hydrogen

2. The green pigment that captures sunlight in plants is:

A) Haemoglobin B) Chlorophyll C) Melanin D) Xanthophyll

3. During respiration, energy is released in the form of:

A) DNA B) ATP C) Protein D) Glucose

4. Which of the following is a product of photosynthesis?

A) Carbon dioxide B) Oxygen C) Water D) Lactic acid

5. What is the main function of stomata?

A) Transport water B) Photosynthesis C) Exchange of gases D) Absorb sunlight

6. Which part of the cell is called the powerhouse?

A) Nucleus B) Ribosome C) Mitochondria D) Chloroplast

7. Which process occurs in green plants during daytime?

A) Respiration only B) Photosynthesis only C) Both D) Neither

8. Glucose is broken down in the cell to release energy during:

A) Photosynthesis B) Germination C) Respiration D) Reproduction

9. Which organelle is involved in photosynthesis?

A) Chloroplast B) Mitochondria C) Ribosome D) Golgi body

10. Anaerobic respiration in muscles produces:

A) Alcohol B) Oxygen C) Lactic acid D) Glucose

11. What is the role of xylem in plants?

A) Transport of water B) Transport of food C) Transport of oxygen D) Storage of starch

12. Which process helps plants make food using sunlight?

A) Digestion B) Photosynthesis C) Transpiration D) Germination

13. Which gas is used during aerobic respiration?

A) Nitrogen B) Oxygen C) Carbon dioxide D) Methane

14. The end product of glucose breakdown in the absence of oxygen is:

A) Water B) Oxygen C) Lactic acid D) Carbon dioxide

15. Which substance is tested using iodine solution in leaves?

A) Sugar B) Protein C) Fat D) Starch

POST-TEST QUESTIONNAIRE (MAI)

Name: ____

School: ____

Class: __________ **Sec:** ________

Gender: **Male** ____ **Female** ____ **Other** ____

INSTRUCTIONS:

This questionnaire is a part of a research study titled *"A Study on the Effect of Metacognitive Instructional Strategies in Promoting Problem-Solving Skills among Secondary Stage Students."* Your responses will be used strictly for academic and research purposes only.

There are no right or wrong answers. The purpose of this tool is to understand your natural way of thinking and solving problems while learning science concepts. Read each item carefully and select the option that best represents your thoughts or behaviours.

Please keep the following points in mind:

1. **Answer honestly** – Respond according to what you actually think or do, not what you believe is the "right" answer.
2. Read each statement carefully. If you feel the statement applies to you, mark **Yes**. If not, mark **No**.
3. **Do not leave any item unanswered.** If you are unsure, make a thoughtful choice.
4. **All responses will remain confidential** and will be used only for the purpose of this academic study.
5. Try not to overthink your answers. **Go with your first instinct** or the option that feels most natural.

Your cooperation is highly appreciated.

S.NO.	Question	Yes	No
Section A: Knowledge of Cognition			
1.	I understand which learning strategies help me the most.		
2.	I can recognize when I am not learning effectively.		
3.	I know how to approach new topics based on my strengths.		
4.	I can clearly identify what I need to learn in a given task.		
5.	I can judge how well I understood something after completing a task.		
6.	I know which types of questions or problems are challenging for me.		
7.	I am aware of how much effort is needed for me to succeed in learning.		
Section B: Regulation of Cognition			
8.	Before starting a task, I decide what methods or tools to use.		
9.	I stay focused on my learning objectives while working.		
10.	If one method doesn't work, I try another way of learning.		
11.	I monitor my progress during learning activities.		
12.	I analyze what went wrong when I make mistakes.		
13.	I revisit difficult material until I understand it better.		
14.	I quiz myself to make sure I remember what I've learned.		
15.	I think about how I handled a learning task and what I could improve.		
16.	I try to connect new topics to what I already know.		
17.	I think about the steps I'm taking during learning.		
18.	I check my understanding by asking myself questions.		

19.	I can explain a concept in different ways to make sure I understand it.		
20.	I try to connect new topics to what I already know.		
Section C: Problem-Solving Awareness			
21.	I think about the problem before jumping to an answer.		
22.	I use trial and error if I am unsure how to solve a question.		
23.	I reflect on the process I used after solving a science problem.		
24.	I try to identify keywords in the question to understand what is being asked.		
25.	I double-check my steps when solving complex questions.		
Section D: Strategy Awareness and Use			
26.	I use learning tools (like mind maps, tables) to organize science information.		
27.	I summarize science topics in a way that helps me remember.		
28.	I highlight or underline important points while learning.		
29.	I change my note-taking style if it’s not helping me understand.		
30.	I solve examples or questions step-by-step to avoid confusion.		

Biology Post-Test Questionnaire

Name (Optional): ____

School: ____

Class: __________ Sec: ________

Gender: Male ____ Female ____ Other ____

Instructions: This questionnaire is a part of a research study titled: **"A Study on the Effect of Metacognitive Instructional Strategies in Promoting Problem-Solving Skills among Secondary Stage Students."**

Your responses will be used strictly for academic and research purposes only. The goal is to understand your current knowledge and thought process related to the biology topic ***Life Processes – Photosynthesis and Respiration.***

Please read the following instructions carefully before beginning the questionnaire:

10. There are a total of **15 questions**, each carrying **2 marks**.
11. The **total marks** for the questionnaire are **30**.
12. **There is no negative marking.**
13. Read each question carefully and select the best possible answer from the options provided.
14. Attempt **all questions**. If you are unsure, choose the answer that seems most appropriate to you.
15. Your responses will be kept **confidential** and will be used only for **research and educational improvement**.
16. Do not overthink your answers—go with your **first instinct**.
17. Take your time and think **critically** about each question. The purpose is to assess not only what you know but also how you apply your understanding to solve problems in science.
18. Your **honest participation** is highly valuable and appreciated.

Thank you for your cooperation.

1. Which factor affects the rate of photosynthesis?

A) Leaf size B) Light intensity C) Wind speed D) Soil colour

2. Which part of a leaf helps in exchange of gases?

A) Midrib B) Veins C) Guard cells D) Epidermis

3. In which form is energy stored in cells?

A) DNA B) RNA C) ATP D) Protein

4. Which component of air is necessary for respiration?

A) Oxygen B) Carbon dioxide C) Nitrogen D) Hydrogen

5. What happens to the glucose produced in photosynthesis?

A) Exhaled B) Stored as starch C) Evaporates D) Used to make proteins

6. Which gas is given out during respiration?

A) Oxygen B) Carbon dioxide C) Hydrogen D) Methane

7. What is common between mitochondria and chloroplasts?

A) Found only in animals B) Energy transformation C) Store DNA D) Involved in respiration

8. Where does anaerobic respiration occur in the body?

A) Brain B) Liver C) Muscles during heavy exercise D) Skin

9. What is the colour change seen in iodine test for starch?

A) Blue-black B) Red C) Yellow D) Green

10. The food prepared by plants is mainly:

A) Protein B) Starch C) Cellulose D) Fat

11. What do stomata do during photosynthesis?

A) Transport food B) Absorb sunlight C) Release oxygen D) Make glucose

12. During aerobic respiration, how many ATP molecules are generated from one glucose molecule?

A) 2 B) 4 C) 36-38 D) 1

13. Which gas is absorbed by leaves from air for photosynthesis?

A) Oxygen B) Carbon dioxide C) Nitrogen D) Argon

14. Why is sunlight important for plants?

A) For respiration B) For growth C) For photosynthesis D) For reproduction

15. Which cell organelle is responsible for energy release?

A) Mitochondria B) Nucleus C) Vacuole D) Endoplasmic reticulum