**1. Introduction**

The paradox at the heart of contemporary educational systems poses an urgent challenge for researchers and practitioners alike: educational outcomes remain strikingly uneven despite decades of reform initiatives. As Boekaerts (1999) and subsequent large-scale policy reports have documented (PISA, 2022; OECD, 2024), the talents of exceptionally capable students remain underdeveloped through insufficient cognitive challenge, and a troubling proportion of struggling learners leave education with fundamental skill deficits despite extensive intervention efforts.

The inconsistent effects of educational interventions are particularly evident in self-regulated learning (SRL) initiatives, where superficially similar approaches produce dramatically different patterns of effects across learner populations. Research on SRL has consistently demonstrated that students' ability to manage their own learning processes is a critical determinant of academic success (Zimmerman, 2008; Pintrich, 2000). Despite this consensus, explaining the differential effects of SRL interventions across achievement levels remains a significant theoretical challenge. Empirical research reveals distinct patterns: compensatory effects, where interventions disproportionately benefit lower-achieving students but provide less value to high-achieving peers (e.g., Pashler et al., 2007; Chang, 2007; Pennequin et al., 2010); Matthew effects, where interventions accelerate already-advantaged students but leave struggling learners further behind (e.g., Otto & Kistner, 2017; Dörrenbächer & Perels, 2016; Lai & Hwang, 2016).

The inconsistent effects of educational interventions frequently stem from regulatory *misalignments* in intervention support with the individual resource. These *misalignments* manifest through either excessive external regulation or insufficient scaffolding for developing essential regulatory capacities. For example, research demonstrates how teacher-dominant regulation simultaneously fosters dependency in students with regulatory deficits and constrains students with stronger self-regulatory capabilities (Boekaerts & Simons, 1995). Excessive external regulation undermines students' intrinsic goal orientation and autonomy perceptions (Niemivirta, 2002), yet inadequate scaffolding leaves struggling students without the phenomenological resources to recognize and respond to regulatory demands (Stoeger et al., 2015).

Efklides' Metacognitive and Affective Model of Self-Regulated Learning (MASRL) offers a theoretical framework for understanding these inconsistent patterns by establishing subjective experiences—particularly metacognitive experiences—as crucial mediating mechanisms between learner characteristics and intervention features. The MASRL model distinguishes two levels of functioning: the Person level (trait-like characteristics) and the Task × Person level (learning event interactions). This distinction clarifies that self-regulation operates at the intersection of person characteristics and task features, with subjective experiences serving as the essential interface between these layers (Efklides, 2006, 2011).

These experiences encompass metacognitive feelings, judgments, and task-specific knowledge activated during cognitive processing. When encountering learning tasks, students do not merely apply cognitive strategies or engage metacognitive knowledge; they navigate dynamic experiences *of familiarity, difficulty, confidence, or satisfaction* that shape their perception of the learning situation. These experiences arise from monitoring cognitive processing and activating prior beliefs, goals, and motivational states (Efklides, 2014). Interventions that neglect this experiential dimension risk addressing merely mechanical aspects of self-regulation, overlooking its dynamic core. Students may learn strategy selection but without attention to how strategies feel—effortful or fluent, satisfying or frustrating, aligned with personal goals or conflicting with them—interventions may fail to produce effective regulatory behavior change.

We propose that differential intervention effects can be explained through a Resource-Intervention Match framework positioning metacognitive experiences as critical mediating mechanisms between learner-intervention alignment and intervention effectiveness. Our framework posits that metacognitive experience quality depends on alignment between interventions and learner proficiency across three dimensions: *Metacognitive Knowledge*, *Metacognitive Regulation Skills*, and *Motivational-Affective Resources*. These dimensions correspond to core components in Efklides' Person level but emphasize their varying proficiency levels and interaction with intervention supports. Metacognitive Knowledge encompasses what learners know about learning, including cognitive strategies and metacognitive knowledge about self, tasks, and strategies (Efklides, 2009; Flavell, 1979). Metacognitive Regulation Skills involve the control processes learners employ through planning, monitoring, adaptation, and evaluation consistent with Zimmerman's (2000) SRL framework. Motivational-Affective Resources address why learners engage and persist, including self-efficacy, values, attributions, and emotion regulation (Pintrich, 2000).

When interventions align with learners' existing resources and scaffold advancement, they create productive metacognitive experiences characterized by accurate formation, adaptive interpretation, and effective utilization (Efklides, 2011). Formation involves how learners become aware of cognitive states through monitoring processes, producing experiences like *feelings of difficulty* or *judgments of learning* (Efklides, 2011; Koriat, 1997). Interpretation transforms these raw experiences into meaningful judgments about cognition, involving attribution processes that connect experiences to causes (Metallidou & Efklides, 2001; Weiner, 1985). Utilization translates interpreted experiences into regulatory actions, bridging awareness and strategic responses (Son & Metcalfe, 2000; Metcalfe, 2009).

Each component exists on a proficiency continuum from basic to advanced. At basic levels, self-regulation remains reactive, externally supported, and characterized by limited metacognitive awareness. At intermediate levels, learners demonstrate increasing independence but benefit from strategic support. At advanced levels, self-regulation becomes proactive, adaptive, and highly calibrated (Zimmerman & Moylan, 2009). The alignment between interventions and learners' existing proficiency determines metacognitive experience quality during learning, which consequently determines differential effect patterns across achievement levels. These components constitute the most proximal and modifiable assets directly influencing SRL outcomes. Unlike stable traits such as intelligence or personality, these components respond to intervention and directly impact regulatory processes (Sontag, 2015, 2019). By specifying the causal chain from SRL component taxonomy through resource-intervention match/mismatch to metacognitive experience quality and ultimately to differential effect patterns, our framework addresses the "black box" problem in aptitude-treatment interaction research (Winne, 1982).

**2. Literature review**

**2.1 Aptitude-Treatment Interaction Theory: The Multidimensional Nature of Learning Resources**

Aptitude-treatment interaction (ATI) theory established that optimal learning outcomes emerge from specific alignments between instructional approaches and learner characteristics rather than from universally effective methods (Cronbach & Snow, 1977; Snow, 1991). Snow (1992) transformed this theory by reconceptualizing aptitude as situation-dependent characteristics that predict success under specific conditions, rejecting static trait models in favor of dynamic person-situation interactions where individual and contextual factors recursively influence each other.

Snow's (1992) concept of "aptitude complexes" established that effective learning depends not on isolated cognitive abilities but on integrated constellations of cognitive, conative, and affective characteristics that interact in complex ways. Snow criticized the tendency of research to isolate single constructs, arguing that "human learners are not just lists of variables" (p. 14). Instead, he proposed a matrix of aptitude constructs with five categories (conceptual structures; procedural skills; learning strategies; self-regulatory functions; motivational orientations) and three degrees of stability (stable, malleable, ephemeral).

Empirical research has validated this multidimensional approach through studies demonstrating how specific resource constraints interact with instructional features to determine learning outcomes. Veenman and Elshout (1995) investigated complex aptitude-treatment interactions involving intelligence and metacognitive skill as aptitudes with structuredness of learning environment as treatment. Their research demonstrated that structured learning environments benefited low-intelligence subjects with poor working methods but impeded learning in low-intelligence subjects with better working methods, which illustrates how separate aptitude dimensions combine to create distinct learning profiles that respond differently to instructional treatments.

**2.1. 2 The Process Gap: Addressing the ATI "Black Box" Problem**

Although ATI research demonstrated the existence of treatment-by-aptitude interactions, the field's most significant theoretical limitation was its failure to specify the psychological mechanisms through which learner characteristics interact with intervention features. Winne (1982) critiqued educational psychology research for lacking construct validity of causal mechanisms, arguing that without adequate specification of mediating processes, researchers could identify patterns of interaction but not explain their occurrence—a limitation mirrored in current research on differential intervention effects in learning

This limitation represents what Winne (1982) termed the "black box problem." He emphasized that understanding how student characteristics interact with instructional features necessitates investigating the mediating processes between them. Winne advocated for replacing the black box approach with a "glass box" methodology that would make transparent the cognitive processes mediating instructional features and learner characteristics. He identified a fundamental theoretical gap: understanding what learners mentally do with content after exposure to instructional stimuli constitutes the central concern for instructional theories (Winne, 1982).

This challenge persists in contemporary research. Dignath and Büttner's (2008) meta-analysis of self-regulated learning interventions demonstrated that strategy training improved academic performance across diverse contexts. However, although researchers hypothesized that strategy instruction enhanced self-regulatory capabilities, the actual processes through which students formed, interpreted, and utilized metacognitive experiences during implementation remained largely ignored. The absence of direct data on these experiential mechanisms obscures why certain SRL interventions produce compensatory effects but others generate Matthew effects.

Building on this concern, Corno (2008) distinguished between macro-adaptation (formal programs designed for groups) and micro-adaptation (ongoing instructional adjustments). Corno proposed that effective adaptive teaching operates through micro-adaptations—moment-by-moment adjustments responding to learners' psychological states.

**2.1.3 Compensatory and Matthew Interactions: Patterns of Differential Effects**

ATI research has identified two primary patterns of interaction that directly parallel the Resource-Intervention Match framework's explanations of compensatory and Matthew effects. Compensatory interactions occur when instructional approaches effectively offset limitations in learner capabilities, providing greater benefits to those with fewer initial resources (Cronbach & Snow, 1977; Corno & Snow, 1986). This pattern corresponds to our concept of compensatory intervention effects, where external support for metacognitive experience processing disproportionately benefits lower-resource learners.

Matthew interactions (also termed "preferential" or "synergistic") occur when instructional approaches leverage existing strengths, providing greater benefits to those with more initial resources (Walberg & Tsai, 1983; Snow, 1989). Corno (2008) described this pattern as a support continuum from high support (circumventing weaknesses) to low support (challenging students to develop strengths). The "teaching middle ground" concept she proposed—where teachers simultaneously adjust instruction to learners and help learners adapt to instruction.

**2.2 Efklides' Theory of Metacognitive Experiences: The Person-Task Interface**

While aptitude-treatment interaction theory provides the process-oriented foundation for understanding differential intervention effects, Efklides' theoretical work on metacognitive experiences offers the essential mechanisms through which these interactions unfold. Where ATI theory established the importance of person-situation interactions, Efklides' framework illuminates the subjective, experiential processes that mediate these interactions. Together, these complementary theoretical perspectives form the integrated framework we propose for understanding differential intervention effects.

**2.2.1 Theoretical Framework: The Dual-Level Architecture of Self-Regulation**

The MASRL model presents a theoretically sophisticated conception of self-regulation by distinguishing between two fundamental levels of functioning: the Person level and the Task × Person level (Efklides, 2011, 2024). The Person level encompasses relatively stable trait-like characteristics including cognitive ability, metacognitive knowledge, motivation, and affect that guide top-down self-regulation. These characteristics function as distal predictors of self-regulatory behaviors, providing the general framework within which regulation occurs. In contrast, the Task × Person level represents the microlevel where actual task processing unfolds, generating immediate subjective experiences that function as proximal predictors of regulatory decisions (Efklides, 2011).

Empirical evidence increasingly demonstrates that online task-specific processes exert stronger influences on self-regulatory behaviors than stable traits alone. Studies examining perceived difficulty reveal that its initial levels and fluctuations during task engagement are more dependent on immediate task-related experiences than on prior achievement or intrinsic value, demonstrating the primacy of situation-specific factors over trait-level characteristics (Efklides et al., 2018). This empirical pattern supports the theoretical proposition that while stable traits establish the general parameters for regulation, it is the immediate subjective experiences that ultimately determine specific regulatory responses.

**2.2.2 Metacognitive Experiences: Definition, Typology, and Functions**

Metacognitive experiences constitute the phenomenological awareness of cognitive states and processes that emerge during task engagement. As Efklides (2006, p. 5) defines them, they encompass "what the person is aware of and what she or he feels when coming across a task and processing the information related to it." This definition highlights their dual nature as both cognitive (awareness) and affective (feeling) components. They manifest in three primary forms: metacognitive feelings (e.g., feeling of difficulty, feeling of familiarity), metacognitive judgments/estimates (e.g., judgment of learning, estimate of effort), and online task-specific knowledge activated during processing (Efklides, 2011).

The critical functional significance of metacognitive experiences stems from their role as interfaces between monitoring and control processes. They make nonconscious monitoring outcomes available to consciousness, thereby enabling deliberate regulatory actions. Without this interfacing function, monitoring information would remain inaccessible to conscious control processes, creating a disconnect between automatic cognitive processing and intentional regulation (Efklides, 2014). This theoretical insight helps explain why learners may possess adequate cognitive resources yet struggle with effective self-regulation—monitoring information remains unavailable for conscious regulatory decisions without sufficient metacognitive experiences.

A key theoretical contribution of the MASRL model is its conceptualization of metacognitive experiences as bidirectional processes involving both bottom-up and top-down influences (Efklides, 2009, 2014). From a bottom-up perspective, metacognitive experiences emerge from monitoring information processing flow and fluency. When processing proceeds smoothly, these experiences may remain minimal, but when difficulties arise due to task complexity, unfamiliarity, or errors, feelings of difficulty interrupt automatic functioning, bringing potential problems into conscious awareness. Empirical studies demonstrate that objective task features consistently influence metacognitive experiences, with more complex tasks generating stronger feelings of difficulty and lower confidence judgments (Efklides & Vlachopoulos, 2012).

Simultaneously, top-down influences from person characteristics shape how metacognitive experiences form and function. Research shows that self-efficacy beliefs mediate interpretations of difficulty, with higher self-efficacy buffering against negative interpretations (Miele et al., 2011). Similarly, achievement goals influence whether difficulty is perceived as a threat or an opportunity for growth, with mastery-oriented learners more likely to interpret difficulty as informative rather than threatening (Efklides et al., 2017). These findings reveal that identical task conditions can generate substantially different metacognitive experiences depending on individual characteristics, explaining why interventions targeting metacognitive processes may produce divergent outcomes for different learners.

Metacognitive experiences operate across different temporal phases of learning, with each phase generating distinctive experiences that inform specific regulatory processes (Efklides, 2011, 2024). Pre-task experiences include anticipatory feelings about task difficulty, familiarity, and confidence that guide task analysis, goal setting, and initial strategy selection. During-task experiences emerge while working on a task and include feelings of knowing, judgments of learning, and progress monitoring that guide ongoing regulation. Post-task experiences occur after completion and include confidence judgments, feelings of satisfaction, and reflections on performance that support learning consolidation and future task approaches.

Metacognitive experiences directly influence learning outcomes through their impact on control decisions and strategy implementation. Research with high-achieving students reveals they establish independent goals, perceive tasks as appropriately challenging, invest greater effort, and report fewer negative metacognitive experiences compared to lower-achieving peers (Snyder et al., 2011). These findings suggest that productive metacognitive experiences facilitate effective learning by promoting adaptive strategy selection and sustained engagement.

Importantly, the relationship between metacognitive experiences and learning outcomes depends substantially on their interpretation. Studies indicate that when students apply the instrumentality heuristic—recognizing difficulty as potentially beneficial for goal achievement—they maintain engagement despite experiencing challenges (Labroo & Kim, 2009). This interpretive process transforms potentially demotivating experiences of difficulty into regulatory resources that support persistence and deeper processing. The critical role of interpretation explains why interventions that merely increase metacognitive awareness without supporting adaptive interpretations may fail to improve outcomes for students lacking interpretive resources.

**2.2.4 Empirical Evidence for the Primacy of Metacognitive Experiences**

The empirical record increasingly demonstrates that subjective experiences exert stronger influence on regulatory decisions than stable traits or even metacognitive knowledge. Studies examining how students respond to challenging tasks have found that immediate experiences of difficulty override trait-level characteristics in determining strategy selection and persistence (Efklides et al., 2018). Research on perceived difficulty reveals that its fluctuations during task engagement are more strongly related to task-specific factors than to general ability levels, demonstrating the context-sensitivity of metacognitive experiences (Efklides & Vlachopoulos, 2012).

Most tellingly, research with high-achieving students shows they not only establish independent goals and invest greater effort but also report qualitatively different metacognitive experiences compared to lower-achieving peers—experiencing less negative affect during difficulty and interpreting challenges as opportunities rather than threats (Snyder et al., 2011). These findings suggest that effective self-regulation depends not merely on having strategic knowledge but on generating and interpreting subjective experiences in adaptive ways

**3. Decomposing Self-Regulated Learning: A Tripartite Framework**

Our framework decomposes self-regulated learning into three fundamental dimensions that interact to determine the quality of metacognitive experiences emerging during learning: *Metacognitive Knowledge Base, Metacognitive Regulation Skills, and Motivational-Affective Resources*. This tripartite structure aligns with but extends previous theoretical models (Efklides, 2011; Pintrich, 2000; Zimmerman, 2008) by focusing specifically on how component-level alignment between existing student resources and intervention features determines the nature and quality of metacognitive experiences that emerge during learning.

**3.1 Metacognitive Knowledge Base**

The Metacognitive Knowledge Base encompasses what learners know about learning processes, including both cognitive strategies and metacognitive awareness. This dimension integrates two distinct but complementary types of knowledge: declarative knowledge about cognition (knowing what) and procedural knowledge about strategy implementation (knowing how). Efklides (2009) characterizes this dimension as awareness of mental processes essential for effective strategy use in learning.

Self-knowledge refers to awareness of one's cognitive strengths, limitations, and preferences (Flavell, 1979). This component progresses from general self-assessments toward calibrated self-understanding through reflective experiences. This includes recognition of personal learning tendencies, domain-specific competencies, and emotional responses to learning situations. Accurate self-knowledge enables learners to make realistic judgments about their capabilities and set appropriate learning goals.

Strategy knowledge encompasses awareness of cognitive and metacognitive approaches for different learning tasks. Pintrich (2000) identified this knowledge as crucial for students' ability to regulate cognition across different phases of learning. Strategy knowledge advances from basic awareness toward sophisticated conditional knowledge—understanding when and why to apply specific strategies.

Task knowledge involves comprehension of cognitive demands and affordances inherent in learning situations, align with Winne and Hardwin's (1998) task definition phase involves learners developing a perception of what the task entails, including its constraints, resources needed, and cognitive demands. Task knowledge includes developing mental representations of completion standards and understanding relevant performance metrics. This knowledge evolves from surface assessments of difficulty toward clear comprehension of task requirements.

**3.2 Metacognitive Regulation Skills**

*Metacognitive Regulation Skills* represent the procedural capabilities through which learners monitor, control, and evaluate their cognitive processes. Although the *Knowledge Base* encompasses what learners know about learning, *Regulation Skills* involve what learners can do to implement that knowledge effectively. These skills develop through practice and feedback, transitioning from externally supported, reactive regulation toward internally generated, proactive regulation (Zimmerman & Moylan, 2009). Metacognitive Regulation Skills include four interrelated but distinct components:

First, *Planning* capabilities establish the foundation for effective learning engagement through deliberate goal-setting, strategic resource allocation, and appropriate strategy selection prior to task initiation. Research demonstrates that planning proficiency serves as a critical differentiator between novice and expert learners, with experts generating more elaborate and conditional plans that anticipate potential obstacles and connect to subsequent regulatory processes (Zimmerman & Moylan, 2009). Intervention effectiveness depends significantly on aligning support with learners' existing planning capabilities—providing structured templates for novices versus metacognitive prompts for advanced learners.

Second, *Monitoring* functions constitute real-time awareness mechanisms through which learners track comprehension, performance, and progress during task execution. Effective monitoring enables accurate assessment of knowledge gaps, comprehension failures, and strategy effectiveness. Interventions targeting monitoring must address both accuracy and timing—novice learners benefit from externalized monitoring scaffolds that prompt regular assessment, but advanced learners respond to interventions fostering internalized monitoring habits through metacognitive questioning.

Third, *Control* and *adaptation* processes represent the responsive adjustment mechanisms triggered by monitoring information. These capabilities include strategy modification, effort regulation, and resource reallocation in response to detected inefficiencies or comprehension failures. Intervention alignment requires calibration between learner adaptability levels and support structures—novices benefit from explicit strategy instruction with guided practice, and advanced learners respond to interventions encouraging flexible strategy selection across diverse contexts.

*Metacognitive Regulation Skills* represent the dynamic, procedural aspect of self-regulation. Students with well-developed regulation skills demonstrate fluid coordination of planning, monitoring, control, and evaluation processes, adapting their approaches based on ongoing feedback. In contrast, students with underdeveloped regulation skills often exhibit fragmented control processes, failing to translate awareness of problems into effective strategy adjustments. Evidence indicates these skills function differently at various proficiency levels—operating as general strategies for novices but transforming into domain-specific regulatory procedures with expertise (Veenman & Elshout, 1999).

**3.3 Motivational-Affective Resources**

Motivational-Affective Resources comprise the psychological assets that energize, direct, and sustain self-regulated learning. These resources determine whether students will engage regulation processes, how much effort they will invest, and how they will respond to challenges or setbacks. Motivational-Affective Resources include four primary components:

First, self-efficacy beliefs reflect confidence in one's ability to execute necessary actions and achieve desired outcomes in specific learning contexts (Bandura, 1997). These beliefs influence willingness to attempt challenging tasks, persistence in the face of obstacles, and resilience following failures. Self-efficacy develops from generalized, often inaccurate assessments of capability toward calibrated, context-specific judgments based on authentic mastery experiences.

Second, value orientations represent the perceived importance, utility, interest, and cost associated with learning tasks and goals (Wigfield & Eccles, 2000). These perceptions influence initial engagement decisions, sustained attention, and depth of processing. Value orientations evolve from externally imposed or instrumental motivations toward personally meaningful, integrated reasons for learning.

Lastly, emotional regulation capabilities involve managing affective responses to learning challenges, including anxiety, frustration, boredom, and pride (Pekrun, 2006). These capabilities determine whether emotions facilitate or impede cognitive and metacognitive processes. Emotional regulation evolves from reactive suppression or avoidance toward proactive modulation and strategic utilization of emotional information.

Motivational-Affective Resources represent the energetic foundation of self-regulation. Students with robust motivational resources demonstrate approach orientations toward challenging tasks, constructive interpretations of difficulties, and effective management of emotional responses. In contrast, students with depleted motivational resources often exhibit avoidance patterns, debilitating attributions, and disruptive emotional reactions that undermine regulation attempts.

**3.4 Level of Proficiency**

Veenman et al. (2006) documented how metacognitive skills evolve from domain-specific, explicit, and effortful to more domain-general, implicit, and automatic. Similarly, Winne (2018) identified distinct acquisition progressions in self-regulation, from primarily reactive regulation guided by external cues to increasingly proactive, autonomous regulation guided by internal standards. These acquisition trajectories are not perfectly synchronous across components—students may demonstrate advanced metacognitive knowledge while still struggling with regulation or motivation—creating complex resource profiles that interact differentially with intervention features.

**3.4 Metacognitive Experiences as Mediating Mechanisms**

The Resource-Intervention Match framework proposes that metacognitive experiences—the subjective awareness of cognitive states and processes that emerge during learning—serve as the critical mediating mechanism between intervention features and learning outcomes (Efklides, 2006). These experiences include metacognitive feelings (e.g., feeling of difficulty, feeling of confidence), metacognitive judgments (e.g., judgment of learning, estimate of effort required), and task-specific knowledge activated during processing.

We propose that metacognitive experiences influence learning through three primary processes: formation, interpretation, and utilization. Formation involves how precisely learners detect and become aware of their cognitive states through monitoring processes. Interpretation involves how learners make meaning of these experiences through attribution and appraisal processes. Utilization involves how learners translate this interpreted awareness into strategic action through control processes.

The quality of these processes depends on the alignment between learners' existing resources and the demands of the learning environment. When interventions align with learners' resource profiles by providing appropriate support for components at their current developmental level while scaffolding advancement to the next level, they create productive metacognitive experiences. These experiences are characterized by accurate formation, adaptive interpretation, and effective utilization, leading to robust learning.

Conversely, when interventions misalign with learners' resource profiles by assuming capabilities not yet developed or failing to provide sufficient scaffolding for advancement, they create unproductive metacognitive experiences. These experiences may include distorted formation (imprecise awareness), maladaptive interpretation (self-defeating attributions), or ineffective utilization (inability to translate awareness into action), undermining learning progress.

**4. Explaining Differential Intervention Effects**

These three broad categories capture the essential elements that determine successful self-regulation and provide a comprehensive structure for understanding differential intervention effects.

**Table 1**

**Components of SRL: Proficiency Levels**

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Basic Level** | **Intermediate Level** | **Advanced Level** |
| **Metacognitive Knowledge** | • Simple, often ineffective cognitive strategies  • Rudimentary understanding of task demands  • Poor calibration of self-assessments | • Broader strategy repertoire with emerging conditional knowledge  • Understanding of basic task demands  • Improved calibration in familiar contexts | • Adaptive strategy repertoire with extensive conditional knowledge  • Strategic task demand  • Accurate calibration across contexts |
| **Metacognitive Regulation Skills** | • Setting simple goals with external guidance  • Following structured plans provided by others  • Periodic checking prompted by external cues  • Basic strategy implementation when directed | • Setting specific goals independently  • Creating basic independent plans  • Self-initiated monitoring, though inconsistent  • Independent strategy adjustments when problems arise | • Developing flexible goals across contexts  • Creating adaptable plans  • Continuous monitoring integrated with adaptation  • Proactive strategy optimization |
| **Motivational-Affective Resources** | • General confidence in learning ability  • External attributions for outcomes  • Limited awareness of learning emotions | • Task-specific confidence  • Mixed attributions with some internal control  • Recognition and management of negative emotions | • Self-efficacy across context  • Strategic attributions that preserve motivation and inform improvement  • Using emotions regulation to enhance learning |

**Table 2**

Intervention Patterns, Features, Resource Alignment, and Subjective Experiences

| **Representative Studies** | **Key Intervention Features** | **Effect Pattern** | **Resource Alignment** | **Subjective Experiences** |
| --- | --- | --- | --- | --- |
| Yan et al. (2020); Pennequin et al. (2010); Chang (2007); Connor et al. (2019) | • Structured scaffolding • Externalized metacognitive processes • Explicit guidance • Progressive support reduction • Clear procedural steps and repeated templates | **Compensatory Effects[gap narrowing effects]** | **Lower-achieving students:** Strong alignment - compensates for metacognitive deficits  **Higher-achieving students:** Poor alignment - creates redundancy with existing skills | **Lower-achieving:** • Feelings of less difficulty • Procedural clarity • Strategic competence • Motivation enhance  **Higher-achieving:** • Feelings of constraint • Redundancy • Boredom |
| Baars & Wijnia (2018); Dörrenbächer & Perels (2016); Lai & Hwang (2016); Schmidt & Ford (2003) | • Complex self-regulation demands • Minimal external structure • High autonomy requirements • Assumes baseline regulatory skills • Limited scaffolding | **Matthew Effects** | **Lower-achieving students:** Poor alignment - assumes resources that aren’t present  **Higher-achieving students:** Strong alignment - leverages existing resources and manageable challenges | **Lower-achieving:** • Confusion • Frustration • Cognitive overload • Disengagement  **Higher-achieving:** • Competence enhancement • Autonomy |
| Chen et al. (2017); De Corte et al. (2004); Donia et al. (2018) | • Adaptive scaffolding • Calibrated to demonstrated competence • Motivation enhancement features • Flexible implementation • Balanced structure-autonomy | **Universal Benefits** | **Lower-achieving students:** Strong alignment - provides needed support  **Higher-achieving students:** Strong alignment - allows for strategy optimization | **Lower-achieving:** • Appropriate challenge • Growing competence • Psychological safety  **Higher-achieving:** • Strategic refinement • Optimal challenge • Continued growth |

*Note.* Metacognitive experiences serve as the critical mediating mechanism between intervention features and learning outcomes. The quality of these experiences depends on the alignment between intervention features and learners’ existing resources.

A diagram of a project

AI-generated content may be incorrect.

A diagram of a person level

AI-generated content may be incorrect.

**4. Synthesis of Empirical Studies**

**4.1 Compensatory Effect Interventions**

Compensatory interventions consistently demonstrate several defining characteristics that specifically target resource constraints faced by lower-achieving students. These interventions externalize metacognitive processes through explicit scaffolding, reduce cognitive load through clear procedural guidance, transform vague intentions into concrete action plans, support accurate calibration of metacognitive judgments, and provide progressive scaffolding that adapts to developing competence.

The most successful compensatory interventions share a common approach of making implicit regulatory processes explicit and accessible. Self-assessment diaries (Yan et al., 2020), structured self-monitoring forms (Chang, 2007), metacognitive prompts (Schwonke et al., 2013), and scaffolded problem-solving heuristics (Peters-Burton & Botov, 2017) all externalize regulatory processes that higher-achieving students typically engage in spontaneously. By providing external structure for these processes, these interventions create productive metacognitive experiences for lower-achieving students who lack the internal resources to generate such experiences independently.

Compensatory interventions specifically target the formation of accurate metacognitive experiences by supporting precise detection of cognitive states and progress. Tools like self-monitoring recording forms (Chang, 2007) and structured reflection prompts (Lizzio & Wilson, 2013) guide students' attention to relevant aspects of their learning processes, helping them develop more accurate awareness of their understanding, effort allocation, and strategy effectiveness. This enhanced metacognitive awareness serves as a foundation for more effective regulation.

These interventions also scaffold the interpretation of metacognitive experiences by supporting constructive meaning-making. Metacognitive training approaches (Pennequin et al., 2010) and academic recovery interventions (Lizzio & Wilson, 2013) help students develop more adaptive attributions for performance outcomes, transforming potentially debilitating experiences of difficulty into informative feedback that guides improvement. This reframing process is particularly beneficial for lower-achieving students who often interpret challenges as evidence of incompetence rather than opportunities for growth.

Finally, compensatory interventions support the utilization of metacognitive awareness by providing clear pathways from monitoring to control. Electronic portfolio systems (Meyer et al., 2010), structured learning diaries (Mou, 2023), and mobile-based self-regulation systems (Shih et al., 2010) establish explicit connections between awareness of learning problems and strategic actions to address them. This scaffolded pathway from recognition to response enhances students' ability to translate metacognitive experiences into effective regulatory behaviors.

These features collectively explain why compensatory interventions benefit lower-achieving students more than their higher-achieving peers. By providing external support for metacognitive experience processing, these interventions create productive subjective experiences for students who lack the internal resources to generate such experiences independently. Higher-achieving students derive less benefit because they already possess these foundational resources, often experiencing the same interventions as unnecessarily constraining or redundant rather than enabling or supportive.

**4.2 Matthew Effect Interventions**

Matthew effect interventions demonstrate a consistent pattern of characteristics that inadvertently widen achievement gaps through differential alignment with learners' existing resources. These interventions typically assume rather than develop foundational metacognitive capabilities, combine multiple sophisticated strategies without adequate integration support, emphasize autonomous implementation without structured pathways for developing independence, require substantial motivational resources for effective engagement, and increase cognitive load without compensatory scaffolding.

These interventions consistently assume baseline levels of metacognitive knowledge and regulation skills that many lower-achieving students lack. Video-based monitoring training (Baars & Wijnia, 2018), self-regulated flipped classroom approaches (Lai & Hwang, 2016), and metacognitive prompting interventions (Schmidt & Ford, 2003; Sitzmann et al., 2009) presuppose that students already possess the foundational understanding and capabilities needed to effectively engage with and benefit from the intervention. Without these prerequisites, lower-achieving students cannot process the intervention content effectively, creating frustrating rather than productive metacognitive experiences.

Matthew effect interventions generate divergent subjective experiences based on students' existing resource levels. Statistical analyses across studies reveal significant interactions between intervention effectiveness and learners' initial capabilities. Dörrenbächer and Perels (2016) found dramatically different responses to their self-regulation intervention based on students' self-regulation profiles, with the largest gains accruing to students who already possessed moderate-to-high motivation while those with low initial motivation showed only marginal improvements. Similarly, Lai and Hwang (2016) demonstrated that higher SRL students showed significantly learning achievements but lower self-regulation students showed no significant differences.

These differences emerge because Matthew effect interventions demand substantial cognitive and motivational resources to process, internalize, and transfer strategies. Higher-achieving students can allocate these resources while maintaining sufficient capacity for content learning, experiencing the interventions as strategic enhancements. In contrast, lower-achieving students experience the interventions as additional cognitive demands competing with core learning tasks, creating feelings of cognitive overload rather than strategic empowerment. As Schmidt and Ford (2003) discovered, metacognitive prompting "had the opposite effect on trainees with a high avoidance orientation," who "reported decreased metacognitive activity and were found to have lower levels of declarative knowledge when provided with the metacognitive intervention."

The divergent subjective experiences generated by Matthew effect interventions directly produce widening achievement gaps. Higher-achieving students experience feelings of insight, integration, and competence enhancement, motivating continued engagement with learning materials. Lower-achieving students experience frustration, confusion, and disengagement, prompting withdrawal from learning processes. These differential emotional and metacognitive responses amplify initial achievement differences, with Otto and Kistner (2017) finding that "whereas the low-achievers' overall strategy application did not change over time, high-achievers could significantly enhance their use of mathematical problem-solving strategies".

**4.3 Universal Benefit Interventions**

Universal benefit interventions share distinctive features that create productive metacognitive experiences across achievement levels. These interventions provide adaptively calibrated support based on demonstrated competence rather than fixed schedules, create psychological safety through design features that minimize defensive responses, offer metacognitive choice within structured frameworks, calibrate challenge levels to create optimal subjective experiences, and integrate self-regulatory training with authentic academic tasks.

The most successful universal interventions provide flexible scaffolding that adapts to individual needs and capabilities. Chen et al.'s (2017) Strategic Resource Use intervention guided students to strategically select and use available resources for exam preparation without prescribing rigid approaches. This flexibility allowed students at different achievement levels to benefit: lower-achieving students gained from the structured approach to resource evaluation, while higher-achieving students benefited from optimizing their existing study strategies. Moderation analyses confirmed "no statistically significant differences in the treatment effect between... low- and high-performing students in both cohorts."

Universal benefit interventions create psychological safety through design features that minimize defensive responses. Donia et al.'s (2018) peer feedback system implemented anonymity features and optimal timing of feedback delivery to reduce evaluation anxiety across achievement levels. By providing feedback after team projects concluded, the intervention created an optimal learning cycle in which emotions had sufficiently subsided to allow cognitive processing of feedback content regardless of initial capability level. This psychological safety enabled both higher and lower-achieving students to process feedback reflectively rather than reactively.

These interventions also provide appropriate levels of challenge across achievement levels through progressive scaffolding based on demonstrated competence. De Corte et al.'s (2004) CLIA intervention adapted support based on students' developing capabilities rather than fixed schedules, providing sufficient structure for lower-achieving students while allowing higher-achieving students the autonomy needed for continued growth. This calibrated approach created an optimal subjective experience of challenge for all students, avoiding both the frustration of excessive difficulty and the boredom of insufficient challenge.

By balancing structure and autonomy, universal benefit interventions accommodate diverse resource profiles while promoting advancement. They provide sufficient external support for students with limited internal resources while offering appropriate challenge and autonomy for students with stronger self-regulatory capabilities. This balanced approach ensures that all students experience productive metacognitive experiences regardless of their initial resource levels, creating consistent learning benefits across achievement levels.