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Beyond the Classroom: The Impact of Sensory Design (Acoustics, Lighting, and Breakout Zones) on Student Regulation and Learning in Special Schools (2015–2025)

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ABSTRACT

The physical design of learning environments plays a critical role in shaping student regulation, engagement, and access to learning, particularly within special school settings where learners often experience heightened sensory sensitivities. This literature-based review examines the impact of key sensory design dimensions—acoustics, lighting, and breakout zones—on student self-regulation and learning in special schools, drawing on peer-reviewed research and policy literature published between 2015 and 2025. Guided by a regulation-as-access perspective, the review integrates evidence from environmental psychology, autism-responsive architectural frameworks, and special education research to explore how sensory conditions mediate students' capacity to remain regulated and instructionally engaged. Findings from the reviewed literature indicate that poor acoustic conditions and inappropriate lighting can increase cognitive load and dysregulation, while sensory-responsive design features and structured breakout spaces can support emotional regulation, de-escalation, and re-engagement with learning. However, the review also identifies significant gaps in the literature, including fragmented examination of sensory dimensions, reliance on short-term and perception-based outcomes, and limited special-school-specific empirical evidence. By synthesizing research across disciplines and policy contexts, this review highlights the need for integrated, evidence-informed sensory design approaches that support regulation as a prerequisite for meaningful participation and learning in special school environments.

Keywords: *Sensory design, special school learning environments, student self-regulation, acoustics and lighting, regulation as access*

INTRODUCTION

Special schools increasingly serve learners whose participation and achievement are tightly coupled with sensory processing, arousal regulation, and environmental predictability. For many neurodivergent learners, classroom demands (language processing, social cues, task switching) can become unmanageable when sensory load is high—especially under poor acoustics, glare/flicker lighting, or overcrowded layouts. Design research since 2015 demonstrates that the built environment contributes measurably to learning variability, with specific sensory factors—particularly light/visual conditions and levels of stimulation—consistently linked to student engagement and performance in school settings (Barrett et al., 2015). More specialized autism-focused design research argues that sensory dimensions—especially **acoustics**, transitions, and escape spaces—function as *regulation supports* rather than aesthetic features, shaping whether students can remain in an "optimal arousal window" long enough to learn (Mostafa, 2018).

Recent national research highlights that many children with special educational needs and disabilities (SEND) are leaving the school system because their needs are not being met effectively within mainstream or specialist settings, underscoring structural and implementation challenges beyond classroom pedagogy and curriculum design. The *Beyond the Classroom* thematic review, conducted by Ofsted and the Care Quality Commission, reports that children with SEND who are not in school often experience inconsistent access to education, health, and social care services, and their families frequently encounter complex systems and resource constraints when attempting to secure appropriate support (Ofsted & CQC, 2025). The review further reveals that lack of early identification of needs, insufficient school capacity, limited staff training, and inadequate joint working across agencies contribute to increased absence and disengagement from formal education, resulting in some children being absent either partially or entirely from school rolls. These findings point to systemic barriers that extend beyond instructional quality into broader issues of access, coordination, and environmental suitability, reinforcing the argument that sensory-responsive design (such as improved acoustics, flexible learning spaces, and breakout zones) must be accompanied by robust structural supports to ensure that students with SEND can remain regulated and meaningfully engaged in learning.

From an acoustics perspective, systematic reviews show strong evidence that background noise, reverberation, and speech intelligibility influence cognitive processing (attention, working memory), communication access, and classroom participation, with particular sensitivity for students with special educational needs (Mogas-Recalde et al., 2021; Mealings, 2016). Autism-specific work further links elevated noise levels to increased repetitive/maladaptive behaviors, suggesting noise is not only a learning barrier but also a behavioral trigger (Kanakri, 2017). In parallel, lighting research indicates that classroom lighting characteristics (illumination, correlated color temperature, and color dynamics) may influence cognitive/affective states and thereby learning readiness; recent quasi-experimental evidence suggests colored/dynamic lighting can produce positive trends in cognitive and affective processes (Quiles-Rodríguez & Palau, 2024), while engineering-oriented work emphasizes "context-responsive" lighting control systems aimed at performance and wellbeing (Chen et al., 2020).

Finally, the growth of sensory rooms and breakout zones (quiet corners, de-escalation alcoves, sensory labs) reflects a shift toward "beyond the classroom" regulation infrastructure. Practice-oriented evidence and evaluations describe these spaces as structured supports for co-regulation and return-to-learning routines (National Council for Special Education [NCSE], 2025) Collaborative school-based research also shows that improving sensory conditions requires participatory processes with staff, pupils, and parents—not just "installing a room" (Martin et al., 2019). Together, this 2015–2025 literature suggests sensory design can be conceptualized as a *regulation and access intervention* that mediates learning outcomes in special schools.

This review adopts a regulation-as-access perspective, viewing sensory design as a prerequisite for meaningful participation and learning in special school environments.

Research Objectives

Based on the growing body of literature emphasizing the role of sensory-responsive environments in special education settings, the present study aims to systematically examine how specific sensory design dimensions within special schools influence student regulation and learning processes.

1. To examine how acoustic design (noise, reverberation, speech clarity) influences student self-regulation and learning participation in special schools.

2. To analyze how lighting design (brightness, glare, color temperature, dynamic/colored lighting) affects attention, emotional regulation, and learning readiness for students in special schools.

3. To evaluate the role of breakout zones (sensory rooms, escape spaces, transition alcoves) in supporting de-escalation, co-regulation, and re-engagement with classroom learning.

Research Questions

In alignment with the stated research objectives, the following research questions are formulated to guide the systematic review and critical analysis of literature concerning sensory design and its impact on regulation and learning in special school environments.

1. How does acoustic design influence student self-regulation and learning participation in special schools?

2. How does lighting design affect attention, emotional regulation, and learning readiness for students in special schools?

3. What role do breakout zones play in supporting de-escalation, co-regulation, and re-engagement with learning in special schools?

Significance of the Study

This study is significant because it reframes sensory design not as an architectural preference but as an equity and access mechanism: when acoustics or lighting reduce sensory overload, students may access instruction more consistently (Mogas-Recalde et al., 2021; Kanakri, 2017). Second, it supports evidence-informed space planning in special schools by integrating design frameworks (e.g., ASPECTSS) with real-world school implementation insights (Mostafa, 2018). Third, it strengthens the "return-to-learning" logic behind breakout zones by linking these spaces to co-regulation routines and school participation outcomes (NCSE, 2025).

Statement of the Problem

Despite rising investment in sensory rooms and "inclusive design," many special schools still operate in environments where noise and reverberation undermine communication and trigger dysregulation (Mealings, 2016; Mogas-Recalde et al., 2021). Similarly, lighting decisions are often driven by energy efficiency or uniform standards rather than neurodivergent sensory needs, even though emerging evidence indicates that lighting characteristics can influence cognitive and affective learning processes (Quiles-Rodríguez & Palau, 2024). This creates a gap between design intent and student outcomes: special schools need an evidence-based synthesis showing which sensory design dimensions matter most, *how* they support regulation, and *under what conditions* they translate into learning gains.

Theoretical Framework (Expanded & Strengthened)

This article adopts an integrated theoretical framework that combines (a) evidence-based learning-space design, (b) autism- and sensory-responsive architectural principles, and (c) regulation-as-access logic. This framework conceptualizes sensory design as an active regulatory mediator between the physical environment and learning outcomes in special schools.

1. Sensory-to-Learning Pathway: Built Environment → Regulation → Participation → Learning

The sensory-to-learning pathway is grounded in the premise that physical learning environments influence students' cognitive and emotional functioning by shaping sensory load and arousal levels. Barrett et al.'s

(2015) SIN model—stimulation, individuality, and naturalness—demonstrates that classroom design variables such as lighting quality, visual complexity, and environmental control significantly predict learning progress. Within this model, *stimulation* is particularly relevant for special schools, as excessive sensory input may overwhelm students' regulatory capacities. For learners with special educational needs, whose executive functioning and sensory modulation may already be compromised, such stressors can lead to rapid dysregulation and withdrawal from learning activities.

Acoustics research strengthens this pathway by providing empirical evidence that sound conditions directly affect speech perception, listening effort, and working memory in classrooms (Mealings, 2016; Mogas-Recalde et al., 2021). These effects are magnified for students with auditory processing difficulties, ADHD, or autism, for whom poor acoustics may result in misinterpretation of instructions and heightened frustration.

Together, these studies support a causal chain in which sensory characteristics of the built environment influence regulation, which in turn determines students' capacity to participate meaningfully in learning activities.

2. ASPECTSS-Informed Autism and Neurodiversity Design Logic

Autism- and neurodiversity-responsive design frameworks provide a more population-specific lens for understanding sensory regulation in special schools. Mostafa's (2018) ASPECTSS™ framework—Acoustics, Spatial sequencing, Escape spaces, Compartmentalization, Transitions, Sensory zoning, and Safety—explicitly links architectural design features to sensory regulation needs of autistic learners. Unlike generic classroom design models, ASPECTSS positions predictability and sensory modulation as prerequisites for learning.

Within this framework, acoustics and spatial sequencing are emphasized as mechanisms for reducing sensory overload and supporting emotional regulation. Empirical studies reinforce this logic by demonstrating that elevated noise levels are associated with increased repetitive and self-stimulatory behaviors in autistic children, indicating a direct link between auditory overload and dysregulation (Kanakri, 2017).

Recent implementation-focused research extends ASPECTSS from theory into practice. Lozott et al. (2023) report that ASPECTSS-informed design interventions—such as acoustical treatment and de-escalation spaces—reduced distractibility and improved classroom management from teachers' perspectives. These findings align with broader neurodiversity scholarship, which argues that environments should be adapted to learners rather than forcing learners to adapt to environments (Milton, 2017).

Thus, autism-responsive design logic conceptualizes sensory design as a preventive regulation strategy, minimizing triggers before behavioral or emotional escalation occurs.

3. Context-Responsive Lighting for Cognitive and Affective Readiness

Lighting occupies a dual position within the theoretical framework: it is both a sensory comfort variable and a biological/psychological regulator. From a neurophysiological perspective, light influences circadian rhythms, alertness, and mood, all of which contribute to learning readiness (Smolders et al., 2015). For students with sensory sensitivities, inappropriate lighting (e.g., glare, flicker, excessive contrast) can act as a persistent stressor that undermines regulation.

Educational lighting research increasingly emphasizes context-responsive and dynamic lighting systems rather than static illumination standards. Chen et al. (2020) propose smart classroom lighting systems that adapt illuminance and correlated color temperature to learning activities, arguing that such systems better support performance and wellbeing than uniform lighting. Empirical classroom research supports this proposition: Quiles-Rodríguez and Palau (2024) found that colored lighting environments produced positive trends in students' cognitive engagement and affective responses, suggesting lighting can influence emotional tone and attentional focus.

National policy on special educational needs and disabilities (SEND) underscores both the scale of need and variability in provision that exist across English schools. According to the UK Government's *Supporting SEND* report, the proportion of pupils with identified SEND has steadily increased in recent years, with approximately 15.5% of pupils in England recognized as having SEND, including a range of needs from mild to complex, such as sensory processing differences and communication difficulties (Department for Education, 2021). The report highlights systemic inconsistencies in how SEND is identified and supported, noting gaps in training, coordination between services, and meaningful co-production with families, which can affect the timeliness and effectiveness of provision (Department for Education, 2021). These findings illustrate a broader challenge: despite clear policy intent to improve outcomes for SEND learners, variability in implementation persists, with implications for how well schools—including both mainstream and specialist settings—can provide tailored environments that truly support regulation and access to learning. This policy landscape reinforces the urgency of designing sensory-responsive educational environments, such as acoustically optimized classrooms, adjustable lighting, and structured breakout spaces, to better meet the regulation needs of students with neurodivergent profiles.

In special education contexts, lighting flexibility is particularly important.

Overall, lighting is theorized as a regulation primer a background condition that either supports calm attentiveness or contributes to cumulative sensory stress.

Literature Gap: Strengths and Weaknesses of Existing Research

The existing body of literature (2015–2025) on sensory design in educational environments provides a valuable foundation for understanding the relationship between the built environment, student regulation, and learning outcomes in special schools. However, a critical assessment of this literature reveals several methodological and conceptual gaps that justify the need for further synthesis and investigation.

Strengths of the Existing Literature

A major strength of the literature lies in its interdisciplinary rigor. Research drawing from environmental psychology, acoustics, architecture, occupational therapy, and special education has collectively established that sensory factors such as noise, lighting, and spatial configuration significantly influence cognitive load, emotional regulation, and classroom participation (Barrett et al., 2015; Mogas-Recalde et al., 2021). Acoustics research, in particular, demonstrates strong methodological robustness, often employing measurable physical variables (e.g., decibel levels, reverberation time, speech intelligibility indices) alongside cognitive and behavioral outcomes, thereby strengthening causal plausibility (Mealings, 2016; Shield & Dockrell, 2016).

Autism- and neurodiversity-focused design frameworks, especially ASPECTSS™, contribute a theoretically grounded understanding of how architectural features align with sensory regulation needs (Mostafa, 2018). Empirical studies further strengthen this contribution by linking elevated noise levels to observable behavioral outcomes such as repetitive or self-stimulatory behaviors in autistic learners (Kanakri, 2017). Similarly, lighting research has advanced beyond basic illumination standards toward experimental and quasi-experimental designs exploring cognitive and affective responses to dynamic or colored lighting environments (Chen et al., 2020; Quiles-Rodríguez & Palau, 2024).

Another notable strength is the growing recognition of breakout zones and sensory rooms as intentional regulatory supports rather than ancillary spaces. Evaluative and policy-oriented studies highlight the potential of these spaces to facilitate co-regulation, de-escalation, and re-engagement with learning when embedded within whole-school strategies (Graham, 2020; NCSE, 2025).

Weaknesses and Methodological Limitations

Despite these strengths, several weaknesses persist across the literature. A primary limitation is the overreliance on short-term or cross-sectional designs, particularly in studies examining breakout zones and classroom modifications. Many investigations emphasize immediate behavioral or perceptual outcomes (e.g., teacher reports of improved calmness or engagement) rather than longitudinal measures of sustained learning or academic progress (Kinnealey et al., 2018; Graham, 2020).

Additionally, a substantial portion of autism-focused design research relies on post-occupancy evaluations and qualitative staff perceptions, which, while valuable, limit generalizability and objectivity (Mostafa, 2018; Lozott et al., 2023). Few studies triangulate environmental data, behavioral observations, and standardized learning outcomes within the same research design, weakening claims of direct impact on learning.

Lighting research, although methodologically innovative, remains heterogeneous in terms of exposure duration, lighting parameters, and outcome measures. This variability makes it difficult to draw consistent conclusions about optimal lighting conditions for students with special educational needs (Quiles-Rodríguez & Palau, 2024). Moreover, most lighting studies are conducted in general education settings, with limited transferability to special school contexts where sensory sensitivities are more pronounced.

Another critical weakness is the fragmentation of sensory dimensions in the literature. Acoustics, lighting, and breakout zones are often examined in isolation, despite evidence that students experience these factors simultaneously. This siloed approach limits understanding of how combined sensory conditions interact to influence regulation and learning.

Identified Literature Gap

Taken together, the reviewed literature reveals a clear gap: while individual sensory design elements are well-documented as influencing regulation and engagement, there is a lack of integrative, regulation-focused synthesis that examines how acoustics, lighting, and breakout zones collectively function as an interconnected support system for learning in special schools.

Specifically, the literature lacks:

1. **Integrated frameworks** that explicitly link sensory design to self-regulation as a prerequisite for learning access.
2. **Longitudinal and mixed-method studies** that examine sustained learning outcomes alongside regulatory behaviors.

3. **Special-school–specific evidence** that moves beyond general education settings and policy guidance to empirically grounded conclusions.

This gap underscores the need for literature-based analyses that move beyond descriptive design features to critically examine how and under what conditions sensory environments support regulation and learning. Addressing this gap contributes to both theoretical advancement and practical guidance for the design and implementation of sensory-responsive special school environments.

Dimensions from Literature

1) Acoustics: noise, reverberation, and speech intelligibility

Systematic review evidence indicates classroom acoustics influence both students and teachers through pathways including cognitive processing and fatigue; key parameters include background noise, reverberation time, and speech clarity (Mogas-Recalde et al., 2021). Standards-focused reviews emphasize that many classrooms do not meet recommended acoustic conditions and that learners with special educational needs require more favorable listening environments (Mealings, 2016). Autism-focused literature highlights the risk of sensory overload from reverberation/noise and argues for acoustic design as an accessibility intervention. (Caldas et al., 2016) Empirical classroom observations show noise levels can correlate with increased repetitive behaviors among autistic preschool children (Kanakri, 2017). A recent systematic literature review focusing on special needs students concludes that poor acoustics can heighten learning challenges and behavioral difficulties, reinforcing the urgency of acoustic interventions in inclusive/special settings (Karim & Khairuddin, 2025).

Design implication: acoustics are not “background quality”; they are instructional access infrastructure.

2) Lighting: brightness, glare, color temperature, and dynamic/colored light

Lighting research between 2015–2025 increasingly shifts from “illumination adequacy” to “learning-responsive lighting.” A smart lighting study argues that illuminance and correlated color temperature can be controlled to support performance, criticizing designs that focus only on energy saving without learning context (Chen et al., 2020). In school-based quasi-experimental work, colored lighting showed positive influence trends on cognitive and affective processes (Quiles-Rodríguez & Palau, 2024). In broader learning-space models, “light” and “stimulation” are identified as key predictors of learning progress (Barrett et al., 2015), supporting lighting as a major design variable rather than an afterthought.

Design implication: lighting should prioritize visual comfort, low sensory stress, and regulation-supportive consistency (avoiding glare, harsh contrast, and poorly controlled dynamics).

3) Breakout zones: sensory rooms, escape spaces, and transition alcoves

Breakout spaces are increasingly described as structured “regulation supports” that enable de-escalation and re-entry to learning when paired with clear routines and staff training (NCSE, 2025). Autism-specific sensory design research emphasizes “escape spaces” and transition areas as core components of supportive environments (Mostafa, 2018), and implementation work reports that introducing de-escalation zones and transition alcoves can support management of disruptive behaviors and improve perceived classroom functioning (Lozott et al., 2023). Collaborative school improvement research also stresses that sensory environment changes work best when co-developed with teachers, parents, and pupils (Martin et al., 2019).

Design implication: breakout zones must be designed and governed as therapeutic-educational bridges, not isolation or exclusion spaces.

Critical Comparison of Literature

Across 2015–2025 studies, a consistent pattern emerges: acoustics has the strongest and most direct evidence base linking physical conditions to comprehension and behavior, while lighting evidence is growing but more heterogeneous, and breakout zones evidence depends heavily on implementation quality.

1. **Strength of Evidence and Measurement**
   Acoustics research benefits from measurable physical variables (dBA, RT, STI) and well-established cognitive mechanisms (speech perception, listening effort), enabling stronger causal plausibility (Mealings, 2016; Mogas-Recalde et al., 2021). Autism-specific findings support this by linking noise to behavioral outcomes (Kanakri, 2017) and framing acoustics as accessibility (Caldas et al., 2016). By comparison, lighting studies vary widely in exposure duration, outcome measures, and contextual controls, leading to mixed findings—though recent classroom studies demonstrate promising cognitive/affective trends (Quiles-Rodríguez & Palau, 2024) and systems research provides implementable models (Chen et al., 2020).

2. **Population Specificity and Transferability to Special Schools**
   General classroom design models (e.g., SIN; Barrett et al., 2015) demonstrate that physical space affects learning broadly, but they are not tailored to neurodivergent sensory profiles. Autism-specific frameworks (Mostafa, 2018; Lozott et al., 2023) provide better conceptual fit for special schools because they integrate escape spaces, sequencing, and sensory zoning. However, some autism-oriented studies rely heavily on staff perception and post-occupancy evaluations, raising questions about objective learning outcome measurement.

3. **Breakout Zones: Intervention or Environment?**
   Breakout zones sit at the intersection of design and practice. Evaluations show that outcomes depend on staff training, access policies, and whether students are taught to use spaces as part of regulation routines (NCSE, 2025). Participatory work reinforces that sensory improvements require collaborative adaptation (Martin et al., 2019). Thus, breakout spaces are best understood as environment-enabled interventions—their success is contingent on governance.

DISCUSSION

Synthesizing the evidence, sensory design affects learning in special schools primarily through regulation stability and instructional accessibility.

Acoustics as regulation protection. Poor acoustics increase listening effort and cognitive load, reducing the capacity available for self-control and learning tasks (Mogas-Recalde et al., 2021). For autistic learners, reverberation/noise can contribute to sensory overload and trigger behavioral escalation, aligning with observed links between noise and repetitive behaviors (Kanakri, 2017). Because special schools often rely on verbal prompting, social communication, and structured routines, acoustic failure becomes an equity issue: students may be labeled “noncompliant” when they are actually overwhelmed by auditory conditions (Mealings, 2016; Karim & Khairuddin, 2025). Therefore, acoustic treatment (absorption, reduced RT, controlled background noise) should be prioritized as a first-line support.

Lighting as cognitive/affective readiness. Lighting influences visual comfort and may also contribute to alertness and emotional tone. Recent classroom evidence suggests colored lighting can positively shape cognitive and affective processes (Quiles-Rodríguez & Palau, 2024), and smart systems research supports tailoring illuminance/CCT to learning contexts rather than using static, one-size-fits-all settings (Chen et al., 2020). In special schools, the practical implication is conservative: avoid sensory stressors (glare, flicker, extreme contrasts) and provide stable, adjustable lighting to support regulation, consistent with broader classroom design evidence emphasizing "light" as a key learning-related variable (Barrett et al., 2015).

Breakout zones as structured re-entry pathways. The literature is clear that sensory rooms and breakout spaces can support regulation—*if* their use is planned and co-regulated. Policy and practice guidance frames these spaces as part of whole-school sensory strategies, complementing empirical findings (NCSE, 2025). Autism-specific design work highlights escape spaces and transitions as core elements in reducing dysregulation and enabling learning continuity (Mostafa, 2018; Lozott et al., 2023). Participatory research further suggests that sensory improvements succeed when pupils, teachers, and parents contribute to identifying triggers and workable adaptations (Martin et al., 2019).

Overall interpretation. The strongest synthesis is that sensory design is most effective when treated as a multi-layer regulation ecosystem: (1) reduce sensory threats (acoustics/lighting), (2) provide predictable transitions, and (3) ensure breakout zones function as "reset then return" supports rather than removal from learning.

CONCLUSION

Between 2015 and 2025, the literature supports a coherent conclusion: sensory design can improve regulation and learning in special schools, but effects are mediated by implementation quality and alignment with neurodivergent needs. Acoustics shows the most robust relationship with learning access and behavior; noise and reverberation undermine comprehension and can trigger dysregulation, especially for autistic learners (Mogas-Recalde et al., 2021; Kanakri, 2017; Mealings, 2016). Lighting evidence is newer and more variable, yet recent work suggests dynamic/colored lighting and context-responsive systems may support cognitive and affective readiness when applied carefully (Quiles-Rodríguez & Palau, 2024; Chen et al., 2020). Breakout zones can be powerful regulation supports when embedded in structured routines and staff capacity building, rather than used informally or punitively (NCSE, 2025)

In practical terms, special schools should prioritize: (a) acoustic remediation as foundational access design, (b) low-stress adjustable lighting with attention to glare/flicker and predictable control, and (c) breakout zones designed and governed as co-regulation and re-engagement pathways. Future research should prioritize robust outcome measures beyond perception-based reports and investigate combined sensory interventions to determine the most effective design configurations for supporting regulation and learning.

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