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SONIC AWARENESS AS LIFELONG LITERACY: A SOUNDSCAPE EXPLORATION STUDY WITH PRIMARY SCHOOL CHILDREN

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Abstract

Auditory development is a lifelong process, beginning with prenatal exposure to acoustic cues and maturing through late adolescence as a complex intersection of biological, cognitive, and social factors. While biological maturation provides the *hardware* for hearing, the reflective, active engagement with one's acoustic environment requires an intentional pedagogical framework. We argue for a continuous soundscape curriculum from pregnancy through high school, using a foundational study with children to demonstrate the necessity of early educational interventions for lifelong sonic awareness. We employed a child-appropriate method with three workshops with 12 students (ages 7–8) at the International School Delft (NL). Utilizing the ISO 12913 frameworks, activities included soundwalks, perceptual mapping, and sound visualization. Findings indicate that while primary-age children are highly sensitive to salient sound events, such as mechanical traffic or human vocalisations, they initially perceive such sounds as isolated occurrences rather than a soundscape. However, repeated listening exercises and creative mapping (using colour and abstract forms) successfully shifted student perception toward understanding the auditory environment as a collective, integrated system. These results suggest that because primary-age listeners are still constructing the ability to interpret auditory scenes, continued education is vital. As students transition into middle and high school, curricula should evolve from basic event identification to the critical evaluation of varying degrees of impact of sound and soundscapes on humans. By fostering soundscape literacy early, we prepare children to move from passive reception to active ownership of their urban sonic environments.

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1. Introduction

Soundscape research has fundamentally shifted contemporary acoustics from purely physics- and engineering-driven sound pressure level metrics to a comprehensive understanding of how human beings perceive and interpret their acoustic environment in context [1]. This paradigm shift, initiated by Schafer [2] and facilitated by the International Organization for Standardization, acknowledges that human auditory experience is subjective, relational, and inherently contextual [1]. However, within the growing body of soundscape literature, current studies mainly focus on adult cohorts. School-age children are observably under-represented in empirical studies, despite spending significant portions of their developmental years in highly complex, socio-technological acoustic environments like schools and playgrounds. Such absence is critical because auditory perception is a fundamental part of a lifelong developmental process that begins in utero and matures well into late adolescence [3], [4]. While biological maturation builds the fundamental neurological hardware required for hearing, the capacity for active, reflective, and critical engagement with the acoustic environment is a socio-cultural competence that requires structured pedagogical training.

This paper argues that auditory literacy should not be left to passive exposure. Instead, we advocate for the implementation of a continuous, lifelong soundscape curriculum spanning from early childhood through secondary education. To demonstrate the necessity and efficacy of early intervention, this study presents empirical findings from a foundational three-part workshop series conducted with 7-to-8-year-old children utilizing a child-adapted variant of the ISO/TS 12913 data collection framework. The results demonstrate how primary school-age children interact with acoustic environments and how they make sense of sounds and sound events.

2. Auditory Development/Pedagogy

Understanding how children interact with soundscapes requires knowledge into how listening as a basic human skill develops. The human auditory system undergoes prolonged structural changes following infancy and early childhood to adolescence and emerging adulthood during periods of intense brain rewiring needed to process information, learn, and form memories [5]. The period between middle childhood and early adolescence (ages 6–12) represents the final structural phase of central auditory cortical maturation [4]. During this phase, children exhibit quantifiable improvements in complex sensory tasks such as speech discrimination in noise, sound segregation, and overcoming auditory masking [3]. Crucially, however, a child's capacity to interpret an acoustic scene is not dictated solely by sensory organ maturation. Non-auditory cognitive factors, including selective attention, working memory, and cognitive executive control, play a decisive role in how an individual synthesises sound events into a holistic cognitive map needed to make sense, and communicate about, the world [3]. School-age children exhibit significantly greater difficulty than adults in sound source recognition and auditory scene analysis, primarily due to an ongoing vulnerability to informational masking and developing auditory streaming abilities [3]. Consequently, the ability to selectively attend to specific sounds, filter out irrelevant acoustic data, and evaluate an acoustic environment as an integrated system is still actively developing during primary school years.

To ground these developmental phases within soundscape theory, we draw upon Barry Truax's acoustic communication framework. Truax [6] posits that listening competence is directly shaped by the listener's life stage, lived experience, and cultural framework or 'cultural text'. The human relationship with sound shifts dynamically over time; an environmental sound that induces cognitive fatigue in an adult might be completely ignored or reinterpreted by a child engaged in high-energy play. Currently, soundscape management in educational institutions is largely reactive and focuses on what ISO 12913-1 describe as personal acoustic management. For instance, schools frequently deploy passive technical solutions, such as providing noise-cancelling headphones to (vulnerable) students during independent study tasks to combat high sound pressure levels. While these interventions address immediate cognitive load challenges, they treat children as passive recipients of an adverse acoustic reality. However, providing them with tools, methods and knowledge can help transform them into future active agents capable of managing, understanding, or eventually co-creating their acoustic environments. Such tools and methods can be beneficial to co-create a desired soundscape as functioning adults in the future.

While highly innovative soundscape education for adults exists within Europe, a critical review of contemporary sound education reveals a significant gap. For instance, Soundtrackcity in Amsterdam engages local adult residents and municipal actors via structured public soundwalks to inform local urban planning [7]. In a formal academic setting, university-level frameworks like the EARS (Education and Applied Research on Soundscapes) seminar by Andre Fiebig and colleagues and the student-led Soundscape TUB project at TU Berlin teach advanced campus sound mapping and field-recording composition [8], [9].

There is a clear absence of formal, practical soundscape curricula tailored specifically to the developmental capacities of infants, children, and school students. Introducing structured listening and appropriate communication practices in early life can function as an analytical framework, translating the abstract notion of sound into concrete, embodied knowledge and skill that can cultivate lifelong practices to seek sonic comfort in a busy world. Moreover, the aim is to foster listening habits in children that support them as sound-conscious individuals of the society with awareness, skills and knowledge about how to live in a sonically habitable world.

3. Method

To empirically ground this theoretical framework and operationalise soundscape awareness, the following section details a multi-stage, child-adapted participatory method executed as a foundational proof-of-concept for soundscape assessment by children. By sequencing the tasks in the study from natural immersion in the acoustic environment to its multi-modal representation and collaborative reflection towards the school's outdoor soundscape, this methodological structure serves dual purposes: it first functions as a diagnostic tool to evaluate childhood developmental boundaries and secondly, provides a blueprint for the primary education tier of a continuous soundscape curriculum. Our approach uses a multi-sensory data collection method to support children in the expression of their soundscape experiences. The empirical study design follows a deliberate, progressive logic: it starts with an initial exploration of children's baseline auditory streaming and sound source tracking advancing to a comparative evaluation of how children semantically and visually map affective states finally providing evidence to children's level of soundscape awareness. Thus, the study incorporated the following research methods: acoustic analysis (by researchers); soundwalk with soundscape assessment and sound identification together with soundscape co-design with children.

3.1. Context and Participation

The empirical investigation was executed in January 2026 at the International School Delft (ISD), Netherlands (Fig. 1). The research site selected was the primary school playground, a complex transitional zone situated between structured indoor learning environments and adjacent municipal urban infrastructure. This spatial context, also illustrated in Fig. 1, produces a dynamic and active acoustic profile featuring a dense mix of human (children shouting, playing), nature (birds chirping, wind interaction with vegetation), and technological sounds (e.g., localised motorised transport from neighbouring lanes). A cohort of 12 students aged 7 and 8 years (5 boys, 7 girls) from the Primary Years Programme (PYP 4) participated. According to Annex A.2 of the ISO/TS 12913-2 framework [10], these children were classified as "local experts" because they have a deeply embedded, daily routine within this specific environment. All participating students had normal hearing capabilities. Ethically, the study implemented a strict two-tiered consent protocol (TU Delft Ethics Board: HREC #7023). Prior to the workshops, informed written consent was secured from parents/legal guardians, and verbal assent was obtained from the children before each individual session, ensuring their right to withdraw freely. The school facilitated the research activities.

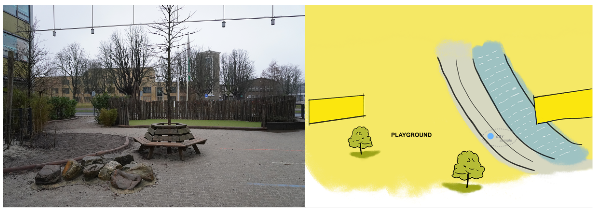

Figure 1: ISD playground (left) and a schematic map for the main play areas, pathways, and sound sources (right).

3.2. Adapting ISO/TS 12913-2 for Children

Our method systematically adapted the data collection protocols specified in ISO/TS 12913-2:2018 to fit children's abilities. Standard soundscape data collection heavily relies on complex semantic differential scales consisting of structured, multi-dimensional perceptually relevant attributes (e.g., calm, chaotic, monotonous, vibrant) as defined in the standard. Because these abstract verbal descriptors do not align with the linguistic and cognitive development of 7-8 year-old children, the study implemented a simpler strategy also requiring students to use visual skills. Thus, the two primary psychological dimensions established by the ISO 12913-2 standard, namely pleasantness and eventfulness, were visually mapped onto a simplified coordinate grid. To capture children's pre-verbal sensory reactions alongside their developing structured verbal interpretations, the protocol was adapted into a child-centered participatory design sequence [11]. Bodily and visual engagement methods were prioritised, drawing on the Cooperative Inquiry Framework where children act as active partners rather than passive subjects [12]. Acoustic environment was recorded using the integrated high-fidelity microphone array of an iPhone 16, and ambient sound pressure levels were cross-monitored utilizing a digital Sound Meter application. See Fig. 3 for the visual representation of the part of the soundscape.

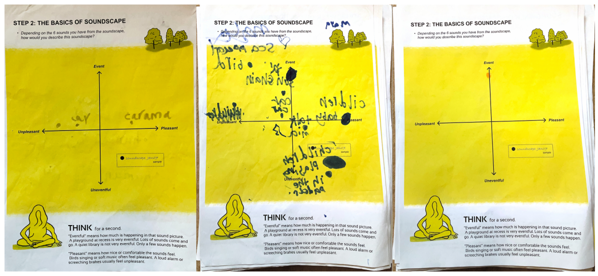

Figure 2: A selection of students' visualisation of soundscape analysis on the two dimensional scale.

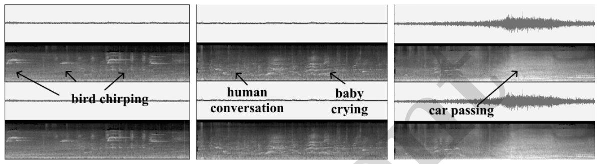

Figure 3: Amplitude visualization of the playground soundscape. (recorded on 19 January 2026).

3.3. Three-Stage Participatory Workshops

The workshop series (see Fig. 4 for a visual reference) was executed across three consecutive weeks, utilizing a progressive pedagogical sequence:

· **Workshop I – Baseline Soundscape Assessment and Visual Mapping:** Grounded in the traditions of the World Soundscape Project [2], students executed a guided soundwalk (2̃0 min) across the playground space following the principles of ISO 12913-2 (Method A). Their task was sound source identification. Following the walk, students mapped their holistic soundscape experience onto a simplified Cartesian plane (eventful and pleasant) translating perceived environmental attributes directly into a visual, spatial layout.

· **Workshop II – Sound Identification and Visualisation of Auditory Experience:** Field recordings from the playground walk (specifically targeting three distinct sources: students screaming, passing cars, and birds chirping) were replayed to the students. Working sheets prompted students to identify and evaluate these sounds using two distinct modalities: i) formal verbal labelling supported by a semantic approach to product sounds to categorise and verbalise three sound events (c.f., [13]) and ii) abstract visual doodle drawing/colour mapping to be able to express their experience and feelings (i.e., an age appropriate expressive task inspired by [12]).

· **Workshop III – Soundscape Re-Evaluation and Co-Design:** A replication soundwalk was performed under quasi-identical environmental conditions to evaluate changes in auditory sensitivity. This was accompanied by a semi-structured focus group evaluating whether children's conceptual understanding of a 'soundscape' had transformed over the course of the intervention (i.e., active engagement with students in Workshop I and II), resulting in a collaborative session by which students proposed their imagined sounds for an ideal playground soundscape.

Figure 4: Different stages of the workshop: soundwalk (top left), visual soundscape assessment (top right), sound identification and visualisation of auditory experience (bottom left) and creating desired soundscape (bottom right).

4. Results

To evaluate the development of children's soundscape literacy, a mixed-methods analytical framework was applied to the data collected across the three participatory workshops. Quantitative assessment involved a frequency analysis of descriptive terms extracted from student worksheets. The terms were systematically categorised using the sound source taxonomy defined in ISO 12913-2, comprising Natural, Human, and Technological/Mechanical sound sources built on Schafer's work [2] and Axelsson and colleagues' classifications [14]. Affective responses were analysed by mapping children's soundscape descriptions against age-appropriate cognitive emotion wheel for basic feelings [15] to measure the psychological impact of specific acoustic stimuli.

Perceptual mapping data from the two-dimensional coordinate tracking system (eventful–uneventful, pleasant–unpleasant) were translated into spatial coordinate system to assess children's capacity for holistic assessment of their acoustic environment. Qualitative data, including audio recordings of focus groups and co-design sessions, underwent thematic content analysis to track the trajectory from sound event identification to systems-level soundscape comprehension. This structural investigation expands upon the fundamental acoustic and pedagogical principles established in the introductory literature overview.

4.1. Workshop I

The first soundwalk yielded a total of 85 discrete sound source identifications across the 12 participant surveys. Technological sounds were most prominent (n=33) such as vehicles, constructions and camera shutter, closely followed by human sounds (n=31) including baby crying, teacher conversation and footsteps, while natural sounds -such as bird chirping, raining and wind blowing-were least reported (n=21) and entirely omitted in several student entries. Within the human sounds category, high-amplitude, transient acoustic events—specifically a baby crying from an adjacent playground—exhibited acoustic salience, capturing the selective attention of all 12 participants. Within the technological sounds, traffic noise such as localised motor vehicles predominated.

A key finding regarding children's auditory scene analysis emerged when two students documented a single passing car as discrete sound events. Specifically, the sound of the car braking, the car passing by and music playing from the same car were recorded as independent sound events. This may indicate that at ages 7-8, children process the same sound source to separate sound events depending on their temporal acoustic patterns rather than continuous sound events.

The exercise to visually map soundscape qualities revealed significant cognitive and developmental boundaries. As illustrated in Fig. 4 (top right), approximately half of the participants struggled with the abstraction of the Cartesian coordinate system. Instead of identifying a unified intersection point to represent the holistic soundscape, students isolated the variables, placing separate marks directly on the individual pleasantness and eventfulness axes. This may suggest that during the baseline assessment, children perceived the acoustic environment as a fragmented collection of isolated events rather than an integrated acoustic system. Moreover, the Cartesian representation seems to be inappropriate for 7-8 year olds.

4.2. Workshop II

During the laboratory playback sessions of recorded sound samples (bird chirping, baby crying, and motor vehicles) of the school soundscape, a cross-modal correlation between visual attributes and affective appraisal spontaneously emerged. Without prompting, participants consistently utilised dark, high-saturation colour fields to express negative affect, while bright, warm tones were reserved for positive emotional states. This behaviour aligns with historical cognitive theories regarding functional colour-emotion pairing [16].

The stimulus of the crying baby provoked the most intense negative hedonic response, with students explicitly labelling the sound as "annoying" and "frightening". Because this stimulus was an authentic field recording of their own peer environment, its negative appraisal indicates that immediate emotional and perceptual reactions can completely override knowledge pertaining to source identification or contextual familiarity. Conversely, the mechanical vehicle stimulus triggered imaginative semantic reinterpretations, with multiple children categorising the passing car as an organic sound, such as a "whale splashing" or a "waterfall". However, despite this creative cognitive shift, affective evaluations remained overwhelmingly negative. This divergence suggests that source categorization and affective appraisal operate independently during childhood auditory processing. Moreover, sounds presented in the absence of their source can cause ambiguity in identification and auditory memory function may not be fully developed [17], [18]. It is possible that children resorted to their imagination to be able to identify ambiguous sounds highlighted in the lack of stable sound-source-label triangulation in a familiar environment.

4.3. Workshop III

The final replication soundwalk and subsequent focus group for co-design of the school soundscape (Fig. 4 bottom right) demonstrated a noticeable change in the children's sonic competence. Working together (three groups of four), peer dynamics facilitated reflection and meta-cognitive awareness. The students' descriptive vocabulary shifted from simple source naming to systemic, relational language, indicating a clearer understanding that a soundscape constitutes a complex composition of concurrent acoustic events rather than a series of disconnected disruptions. For example, in the first soundwalk children described "the baby crying was annoying" and "the bird chirping was joyful". But in the co-creation session they proposed to put a tree near the area where children always cry so that there could be birds to "balance with the annoying sound in the whole space". Repeated exposure to structured listening effectively promoted a transition toward systems-level complex perception. However, the proactive co-design phase exposed a clear divergence between visual and auditory imagination. When prompted to map out and propose an idealised playground soundscape, children experienced significant cognitive barrier trying to imagine alternative acoustic environments while physically immersed in the active, real-time soundscape of the existing playground.

When evaluating their idealised acoustic preferences via colour-coded thematic notes, the children expressed an explicit rejection of sudden, burst-like acoustic impulses (e.g., screaming or crying). In contrast, their desired additions focused on natural elements (e.g. wave, rainbow, birds, waterfalls) and structured, harmonious human sounds (e.g. calming music). This polarization directly demonstrates the early childhood manifestation of "sound romance" and "sound phobia," confirming that young listeners actively crave organic, balanced environmental features that are absent from their daily urban context.

5. Discussion

This study successfully operationalised a child-focused soundscape approach to investigate how primary school-age children interact with, and make sense of, their acoustic environments. The empirical findings confirm that while children (aged 7-8) possess acute auditory sensitivity, their baseline perception is heavily dominated by isolated "sound events" rather than a holistic soundscape. This selective attention and fragmented auditory scene analysis validate established developmental frameworks, confirming that cognitive executive control and auditory streaming abilities are still actively under construction during primary education [3], [4]. Furthermore, the children's imaginative reinterpretation of technological sounds as organic elements and their explicit desire for natural sounds demonstrate early manifestations of "sound romance," highlighting that young listeners' interpretations are deeply shaped by their specific life stage and contextual frameworks [2], [6].

Methodologically, the child-adapted participatory framework proved highly effective at bypassing developmental linguistic boundaries for some tasks. Utilizing non-verbal, embodied modalities—such as abstract drawing and psychoacoustic colour mapping—allowed participants to externalise complex affective and structural responses that are otherwise difficult to convey through words alone. These methods successfully shaped a cognitive shift from basic sound identification to a systems-level awareness of the acoustic environment [1]. This transformation directly addresses a critical educational gap, moving beyond reactive, passive personal acoustic management toward the active cultivation of a lifelong practices that fosters critical thinking on the acoustic environment they are exposed to. Ultimately, this research provides scalability for a continuous soundscape curriculum, ensuring children develop into active agents and literate co-designers capable of shaping a sonically habitable world.

6. Lifelong Soundscape Education

To operationalise a developmental trajectory, we propose a longitudinal, six-phase pedagogical framework designed to systematically scaffold soundscape awareness and cultivate an active sonic awareness from gestation through late adolescence. The framework's initial two phases are pre-systemic, relying explicitly on public health directives, parental intervention, and caregiver management without requiring the active, conscious participation of the child: **Phase 1 (Gestation)**prioritises maternal education regarding prenatal exposure to sound, providing data-driven knowledge on the physiological thresholds of varying loudness and noise levels and their effect on the auditory development of the foetus; **Phase 2 (Infancy)**equips caregivers with the targeted skills to communicate intentionally about sounding objects, using acoustic stimuli to actively shape early language development and environmental comprehension. These phases focus more on perceptual processes and the act of listening.

Once children enter institutionalised schooling, the curriculum transitions into a standardised, progressive matrix of learning goals that adapt to their evolving cognitive capacities: **Phase 3 (Pre-school)** trains children to verbally describe, localise, and identify specific environmental sound sources; **Phase 4 (Primary School)** aligns with the child's expanding emotional development, teaching them to analyse the psychological effects of individual sounds and deliberately separate their affective responses toward wanted and unwanted acoustic stimuli; **Phase 5 (Middle School)** introduces the formalised concept of the *soundscape*, shifting the analytical lens from isolated sound events

to contextually dependent acoustic systems where multiple, concurrent sources exert a collective influence on spatial perception and environmental understanding; lastly, **Phase 6 (High School)** examines the macro-societal impacts of noise pollution and unwanted sound on long-term public health and well-being.
Inline with the systemic ethos of the Sustainable Development Goals and EU funded EqualLife project [19], this trajectory with six phases equips (unborn) children and young adults with the critical diagnostic tools and agency to make socio-acoustically responsible life choices. Through such an institutionalised pedagogical continuum, children gradually transform from being passive recipients of urban noise into articulate, technically skilled agents equipped with the language, methodologies, and skills required to actively design and advocate for global sonic habitability. However, there is still much to do to achieve this goal.

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