

A Methodology for Measuring Children's Visual and Non-visual Sensorial Experiences of Nature: Child-Nature-Distance Case Studies within Primary School Spaces in Glasgow, Scotland.

Revised Title:

An Application of Measuring Visual and Non-visual Sensorial Experiences of Nature for Children within Primary School Spaces: Child-Nature-Distance Case studies in Glasgow, Scotland

Revised Abstract

Proximity to Nature is essential to a child's development. Well-designed educational environments are crucial to supporting this proximity, particularly in the early years of schooling. This study measures children's experiences of Nature within three primary-school spaces at various locations in Glasgow, Scotland. The methodology for measuring children's visual and non-visual sensory experiences is developed to evaluate the connection between naturalness values and spatial environmental qualities across varying 'Child-Nature-Distance' (C-N-D) ranges. The approach associates children's multiple layers of sensory modalities with particular attributes of the spatial environment within primary schools to determine the level of naturalness that children experience, in both internal and external spaces. The study finds that children's experiences are significantly influenced by factors relating to urban setting, built environment master planning, architectural features, and interior design. The authors argue that the application of this method can support design decision-making for refurbishing schools at the micro level, and in planning urban development involving proposals for new schools at the macro level.

Keywords

Naturalness value, Sensorial experience, Permeability, Spatial environment, Primary schools, Nature Syntax

INTRODUCTION

Recent empirical evidence indicates that a connection with Nature contributes positively to children's constructive development. Related research has involved studies in children's health and well-being (Bell et al., 2008; Cleland et al., 2008; Mayer et al., 2008; McCracken et al., 2016; Taylor and Kuo, 2006), approaches for the psychological phenomenon 'environmental generation amnesia' (Chipeniuk, 1995; Kahn Jr., 2002; Laaksoharju and Rappe, 2017), and children's behaviour and attitude informing environmental moral constructions for sustainability (Cheng and Monroe, 2012; Collado et al., 2013; Frantz and Mayer, 2014). Considering the positive effects of the natural involvement on children, the creation of appropriate environments within which children can be exposed to Nature is essential. According to North Carolina State Professor Robin Moore, the pivotal role of the natural experience via sensorial modals and the needs for children's development has indicated that:

Children live through their sense. Sensory experiences link the child's exterior world with their interior, hidden, affective world. Since the natural environment is the principal source of sensory stimulation, freedom to explore and play with the outdoor environment through the senses in their own space and time is essential for healthy development of an interior life. (Louv, 2006, p. 34)

Multi-sensory diverse engagements with the natural world are considered, within this study, as integral to the enrichment of children's romantic memories and to a life-long love of Nature (biophilia). Children between the ages of 7 and 12 years old were selected for the study since, within an educational framework this phase of their development is supported by daily, direct and meaningful connections with their natural surroundings. Primary-school children are considered to have an environmental experience range ten times greater than those under 6-year-old and over 12-year-old (Heerwagen and Orians, 2002). This 'early-middle' age group also exhibits significant intellectual development associated with surrounding creatures and natural settings (Kellert, 2002; Miller and Kuhaneck, 2008). However, within an educational context, the diversity of natural experience for these children has been diminished through the urbanization process, whereby the proximities of natural environments to school sites in cities are increasingly at extended distance scales. This presents challenges in primary school architectural design and decision-making processes when considering how to "*move children to nature*" and "*bring nature closer to children*" (Turner et al., 2004) and, more broadly, in addressing ways to bridge the widening gap between humans and Nature (Grierson, 2009).

Within this framework, the present study aims to evaluate the children's connecting with Nature in three educational spaces for the children age group from 7 to 12 years old of The Glasgow Academy in various locations in Glasgow, Scotland. These case studies are chosen because of their significant differences in spatial environmental attributes and in order to explore impact factors of the naturalness value measurement of the children's multi-sensorial experiences of Nature.

The authors contend that a comprehensive examination of natural environment characteristics which can be directly connected to a child's sensorial modalities can in part address these challenges and help in re-thinking, re-forming and re-designing proposals for children's learning and leisure places. However, previous tools for natural environment assessment, ranging from the nearby nature, to urban greenspaces, to wilderness areas, have focused on typology (based on land use databases or classification of land cover data) and/or the quality of the natural environment (and have also varied between disciplines regarding the human's perceived environmental ranges and how the natural environment contributes to human's physical, psychological, and interactional aspects) (Arriaza et al., 2004; van Den Berg et al., 2017; van Dillen et al., 2012; Gidlow et al., 2018, 2012; Palmer, 2004; Pálsdóttir et al., 2018; Wheeler et al., 2015). However, less attention has been given in the relevant literature to the existent value of naturalness which directly impacts

the human body via sensory modalities. This can be interpreted as the value of external “cause” while methods that obtain data from responses of populations bring “perceived” value due to the internal “*appraisal of core affect*” according to the model of human’s experiencing nature (Linzmayr et al., 2014). Although the recent Space/Nature Syntax method (Munro and Grierson, 2016) introduces this aspect, the method limits investigation to the visual connection of the Human-Nature relationship within the context of social distance. This paper recognises the need to expand this investigation by exploring the qualification of naturalness in a particular place to a more holistic visual and non-visual sensorial experience. Furthermore, it acknowledges that the varying value of Nature in relation to distance features has not yet been sufficiently investigated. In particular, it attempts to support a proximity hypothesis – that closer connections bring greater benefits to children; and that the proximity of Nature at distances where a child has direct and meaningful sensory exposure is a vital requirement for the primary-school children group selected. Through particular contexts of case studies, this paper proposes and demonstrates the application of a developed methodology for measuring children’s visual and non-visual sensorial experiences by connecting naturalness values with spatial environmental qualities across varying ‘Child-Nature-Distance’ (C-N-D) ranges. It asks a key question, “How much Nature exists in the limited distances of a child’s visual and non-visual experience in both internal and external spaces with particular spatial attributes **of the educational environments?**” Within the C-N-D ranges, three value measurement parameters which reflect the correlation between a child and Nature are defined as: *Permeability* (referring to the accessibility of children to nature and vice versa), *Impact* (referring to distance between the natural source and a child), and *Naturalness* (referring to the properties of Nature in accordance with land coverage planning).

Overall, this paper first gives a brief introduction of three case studies of The Glasgow Academy. This is followed by a description of the methodological approach of the research including an overview of specific features of our sensory modality system. The results of the defined application are then discussed. Finally, the paper concludes with a brief summary of the study’s possible contribution to decision-making at a micro and macro level.

CASE STUDIES: THREE PRIMARY SCHOOLS OF THE GLASGOW ACADEMY, GLASGOW

Three primary-schools of The Glasgow Academy (TGA), including TGA_Kelvinbridge, TGA_Milngavie, and TGA_Newlands, provided the locations for this study. These schools were selected since they offered considerable differences in spatial configurations and architectural features of classrooms and playground settings for primary-school children, and distinct locations within an urban setting (Figure 1). TGA is a private school within the Scottish education system and so the majority of its pupils are from higher-income families residing in and around Glasgow. Although children’s access and proximity to Nature can be linked to broader socioeconomic factors, this paper focuses on the connection between naturalness values and spatial environmental qualities across varying ‘Child-Nature-Distance’ (C-N-D) ranges, rather than the social implications of the methodology, which will be the subject of a related study involving pupils within a contrasting social, cultural, and economic setting.

Particularly, the school of Kelvinbridge is located in the high density area of city; however, its site is surrounded by a river landscape and diversity green spaces. In another condition, the school in Milngavie is set within a residential area in the suburb north Glasgow, and its pupils have three various outdoor playing areas in which a wilderness is part of the school’s facility. TGA_Newlands primary-school placed in the residential area of Mansionhouse Gardens estate side is covered by crossroads and private houses. With regard to internal spaces, five classrooms and playgrounds were selected in order to analyse the value of naturalness for ‘whole and part’ studies of children’s visual and non-visual experiences. In particular,

- TGA_Kelvinbridge: 3 classrooms, in which rooms TGA_K_P3 (at 2nd floor) and TGA_K_P4 (at 3rd floor) have similarities of locations within the recently built building of the school master planning with modern design, while TGA_K_P7 is placed at the ground floor of the older building at the main gate side; a playground TGA_K_O (Figure 3a).

- TGA_Milngavie: 1 classroom TGA_M_P3&4; 3 different playground areas are labelled as: TGA_M_O1 (area at entrance), TGA_M_O2 (Hard playground), TGA_M_O3 (Wild area) (Figure 3b).
- TGA_Newlands: 1 classroom TGA_N_P3&4; and the playground TGA_N_O (Figure 3c).

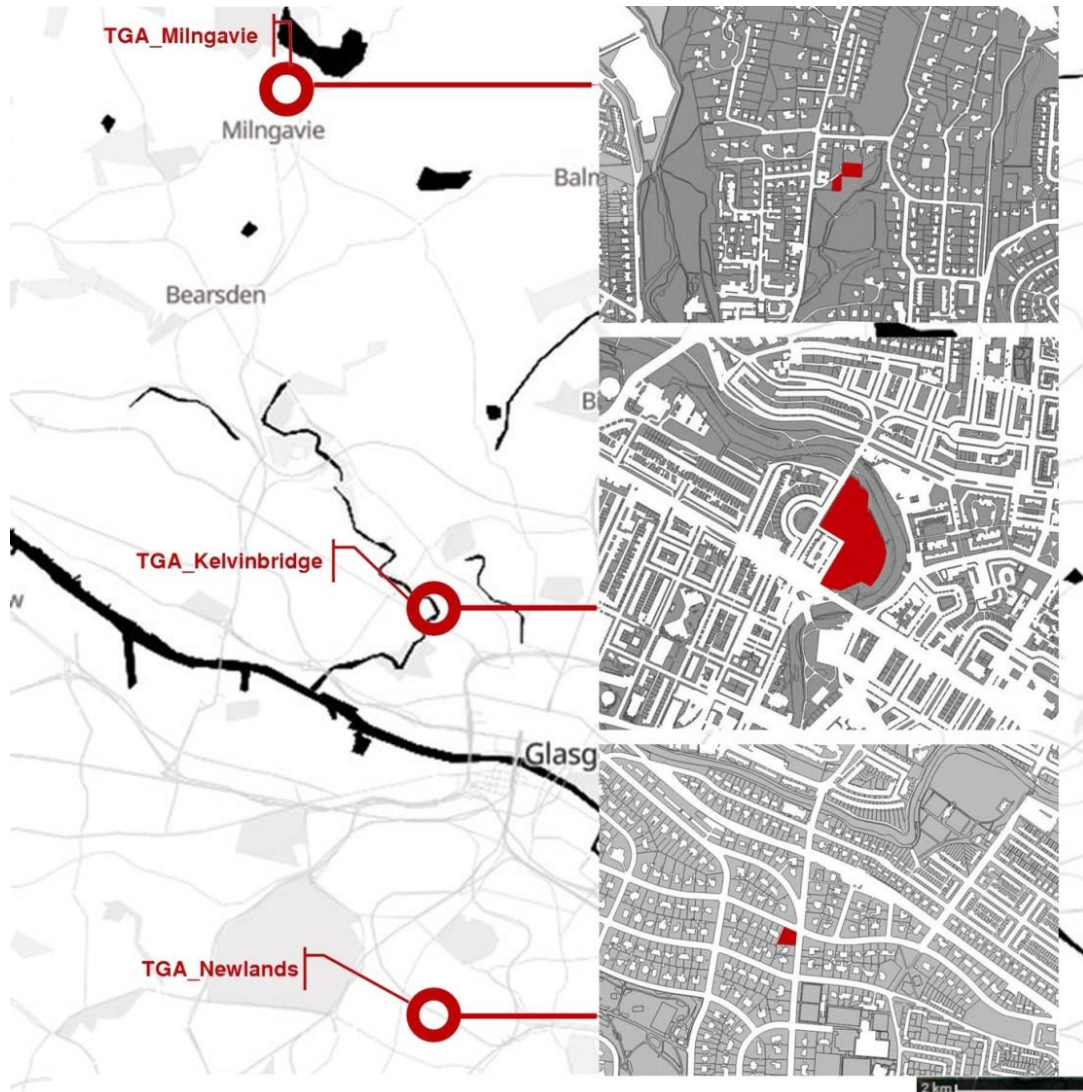


Figure 1. The locations of three TGA primary schools in the Greenspace Maps of Glasgow.

(Source of the background map: https://www.gosur.com/map/united-kingdom_scotland_glasgow/; Source of Greenspace maps: Scotland's Greenspace Map from Digimap Resources Centre (<http://digimap.edina.ac.uk/>))

METHODOLOGICAL APPROACH

According to psychologist James J Gibson (Bloomer, 1977, p. 44), our senses are categorized in five sensorial systems, namely Visual system (looking), Auditory system (hearing), the Taste-Smell system (tasting and smelling), the basic-orienting system which leads man to seek a symmetrical balance in *“the relationship between the horizontal ground plane and our vertical posture”* (Malnar and Vodvarka, 2004, p. 42), and the haptic system (touching). In spatial interactions – Senses of Space - which is both *‘biomorphic and anthropological’* (Simonsen, 2005), excluding the basic-orienting system, the human body identifies space through Looking, Hearing, Touching, Tasting and Smelling. In order to gain a better understanding of how much naturalness a child directly experiencing within the observed space, the methodology abstracts the child's multiple layers of sensory experience, so that each layer can be examined in relation to spatial attributes. In this study, the value of naturalness is designated as a positive force or essence of the surrounding environment affecting the physical body of a child within the human's anthropological sensorial

experiencing distance. Each place generates different 'real' naturalness values, irrespective of whether the child can or cannot perceive the existence of natural elements. In considering Nature within the spatial environment, five sensorial systems are arranged coequally and measured within the Child-Nature-Distance ranges designating specific biological and anthropological characteristics.

Features of sensory modality

The sensory apparatus are classified into two groups, including the '*Distance*' senses and the '*Close or Immediate*' senses (Gehl, 2010, pp. 31–59; Hall, 1966, pp. 40–43). Looking, hearing and smelling are positioned in the '*Distance*' group since they are concerned with the examination of distant objects using our eyes, ears and nose; while touching and tasting are related to examining the closed surrounding world via our skin, membranes and muscles. Additionally, referring to the particular character of each sense, human's experience via looking is controlled by '*directional*' effect while other senses are '*omnidirectional*'.

In consideration of our experiences of Nature in an urban setting, each sensorial system has specific features varying the interval change effect and the content of the natural environment. Particularly, Gehl suggests 100-meter radius as '*the distance of human's experiences*' (2010, pp. 31–59). This value is reasonably proportionate to the limited distance of the human's visual field. People with unaided eyes can obtain the information within 100 yards (91.44 meters) radius, and remain effective until a mile (1609.34 meters) (Hall, 1966).

Regarding our sense of hearing, in general, the human's sound sources of a place, defined as '*soundscape*', are classified into three primary classes: *biophony* (sounds produced by all organisms of nature, such as the songs of birds and insects), *geophony* (sounds originated from the geophysical environment, e.g. the sound of running water, of falling rain, of wind rustling through leaves), and *anthrophony* (sounds created by human activities); the integration of these sounds across the landscape generates a '*soundscape*' (Pijanowski et al., 2011). A compounded mixture of various sound sources is the consequence of many land-use and land-cover classes within an area and its neighbouring contexts (Zhang and Kang, 2007). Ranges of integration with human auditory distances are explored by Gehl (2010) and Lazarus (1986), confirming that people can hear shouts (range from 84dB to 96dB) within 70 meter distance, get one-way communication at loud voice within 35 meters (between 72dB and 78dB), and confirming that when the distance between sound sources is reduced more detailed and articulated hearing levels are achieved.

Regarding our sense of smell, this is believed to awaken more intensive memories than other sensations (Hall, 1966) as well as define places through spatially ordered, or place-related, scent recollection and recognition as given in the concept of '*Smellscape*' (Kubartz, 2014). According to Porteous (1985), factors, including the *source* of a smell, *air currents*, *direction and distance from the source*, primarily affect to the permeable degree of human, especially in the period of childhood (at around age 7). He also described the relationship between smell and spatial dimensions of a place. Through features of a place, smells apparently provide and indicate olfactory sensations, give particular information of urban landscape, natural and built environment settings in the combinations with the messages of seasons and time changes. Distinctions between urban and rural areas are probably recognized through the differences in the density and variety of plants and accompanying biological systems. Like with hearing the acuity of our sense of smell also changes according to the distance scale.

Due to particular features of '*close*' or '*immediate*' experiencing, the senses of touch and taste are generally considered at distances where 'hands can touch' or 'mouths can taste'. However, there is an exceptional consideration when regarding these senses in the context of 'imported' Nature. The possibility exists of an impact resonance in which natural elements' transition (e.g. from far distances to a child's reachable distances) through external agency or are self-collected into an environment. Hence, as previously mentioned, within the method, the child's perception and awareness are not considered when the existing value of the 'real' natural environment is calculated, rather features of touching and tasting provide references to the connectivity between the nearby (*peripersonal*) environment and the distal (*extrapersonal*) environments. Consequently, the proximity of the natural resource to a child is reflected in the C-N-D; i.e.

when natural elements are closer to a child, there is a higher prospect of touching and tasting, and vice versa.

The specific characteristics of visual and non-visual sensorial modalities in consideration of the Human – Nature connection in an urban setting are summarised in Table 1.

Table 1. Features of sensory modalities in Human-Nature connections (Source: Authors)

	Features of Human – Nature connection via senses				
	<i>'Distance' experience</i>	<i>'Close' experience</i>	<i>'Directional' effect</i>	<i>'Omnidirectional' effect</i>	<i>Interval variation effect</i>
Looking	•		•		•
Hearing	•			•	•
Smelling	•			•	•
Tasting		•		•	•
Touching		•		•	•

According to distinct features of each human’s sensorial modality in the Human-Nature connection, the principal concepts are as follows:

- The features of *'distance'* and *'close'* experiences are associated with the permeable range of the built envelopes belonging the observed spatial environment;
- Due to the *'directional'* feature, the naturalness of vision is distinctly figured by DepthMapX software to quantify the permeable surface area of vision while other senses obtain the similar values of naturalness;
- The effects of interval variations which are indicated by the Child–Nature–Distance (C–N–D) ranges are defined as the impact values, and these values are adopted to calculate the value of naturalness of each sense.

METHODOLOGY

To define the value of Nature experienced within the spatial environment, there are three statistical parameter systems: (1) The Permeability value; (2) The Impact value; and (3) The Naturalness of Looking, Hearing, Touching, Smelling and Tasting. These figures are applied to determine the Total and sub- Values of Naturalness of a space, which reflect (in 'whole and part' studies) the interaction between a child and Nature within the teaching and leisure spaces of a primary school.

Parameter 1 - The Permeability value

The term *'Permeability'* refers to the relationship between the built and natural environments through architectural features of the building envelopes. Firstly, features of building envelopes of the observed space are defined and figured in Table 2.

Table 2. Values of building envelope features (Source: Authors)

Looking	(FV): Visibility of an envelope of the observed
	FV = 1.00 visible transmittance (transparent)
	FV = 0.50 partly visible transmittance (only for lighting)
	FV = 0.00 non-visible transmittance
Touching	(FC): Connectivity of an envelope of the observed space with the exposed natural environment
Smelling	FC = 1.00 Opening (e.g. window can be opened for natural ventilation)
Tasting	FC = 0.00 Fixed (e.g. glass window attached completely for visibility only)
Hearing	(NI): Noise insulation of an envelope of the observed space with the exposed natural environment
	NI = 1.00 Opening
	NI = 0.50 Using materials for the built environment without the specific requirement of noise insulation (e.g., general classrooms of the primary school, class base, general teaching area, small group room)*

NI = 0.00 Using materials for the built environment with higher level or specific requirement of noise insulation (e.g., music classroom, library)*

* These values are given according to regulations for Primary schools of 'BB93: Acoustic design of Schools: Performance standards - Building Bulletin 93 (BB93) (Last updated 19 December 2014) (The Department for Education (DfE), 2014)

The **Total Permeability values** of the observed space, which includes three specific sub-values **Permeability of Noise insulation (PNI)**, **Permeability of Connectivity (PC)** and **Permeability of Visibility (PV)**, is specified as the average value of proportional permeability parameter of internal sections (Table 3). In particular, the **values of PNI, PC and PV of each section (S_i)** are labelled as S_{i_PNI}, S_{i_PC}, and S_{i_PV}. They are referred to the **percentage of Permeable Surface Area (S_{i_PSA})** to the **Total Surface Area (S_{i_TSA})** of the examined envelope, and features of building envelopes which are classified and given in Table 2. When the **Sectional Permeability (S_{i_PNI}, S_{i_PC}, S_{i_PV})** attains the value of (1.00, 1.00, 1.00), the observed internal section S_i connects entirely with its surrounding natural environment.

The **P-values (PNI, PC, PV)** therefore represent the amount of five sensorial connections from the studied area to its exposed natural environment, through a statistical value between 0.000 and 1.000 where 0.000 is the space which is completely segregated from its surrounding natural environment, and 1.000 is the space which is entirely connected to its nature-at-the-doorstep.

Table 3.Parameter 1 – The Permeability values of a space (Source: Authors)

S _i								Total Permeability values of the observed space		
Area (sqm.)		Feature			Permeability of S _i			Noise insulation	Connectivity	Visibility
Total surface area	Permeable surface area	Noise insulation	Connectivity	Visibility	Noise insulation	Connectivity	Visibility			
S _{i_TSA}	S _{i_PSA}	S _{i_NI}	S _{i_FC}	S _{i_FV}	S _{i_PNI}	S _{i_PC}	S _{i_PV}	PNI	PC	PV
					$\frac{S_{i_PSA} \times S_{i_NI}}{S_{i_TSA}}$	$\frac{S_{i_PSA} \times S_{i_FC}}{S_{i_TSA}}$	$\frac{S_{i_PSA} \times S_{i_FV}}{S_{i_TSA}}$	$\frac{\sum_{i=1}^n S_{i_PNI}}{n}$	$\frac{\sum_{i=1}^n S_{i_PC}}{n}$	$\frac{\sum_{i=1}^n S_{i_PV}}{n}$

Parameter 2 – The Impact value (IV) - Child–Nature–Distance (C–N–D) ranges

Based on the considerations of interval change effect of visual and non-visual sensorial experience with nature, the parameter of C–N–D ranges are used to refer to the impact value of the distance from the natural resource to a child. The 100-meter horizontal distance, as Gehl's 'distance of human's experience', is applied to limit the field of the observed area for both visual and non-visual senses. In this study of the primary school architecture, the observed spaces are the classroom and outdoor playgrounds where children study and play each weekday.

In the Table 4, the C–N–D includes four statements by which the impact values are labelled as follows: 1.00 = within the studied space (on-site), 0.75 = within the school site boundary to the 50-meter distance, 0.50 = within the 50-meter to 70-meter distance, 0.25 = within the 70-meter to 100-meter distance.

Following this, the **Impact value (IV)** ranges between 0.25 and 1.00, where 0.25 is the degree of influence to a child's senses at the distance from 70-meter to 100-meter, and 1.00 is the highest degree of a child's absorption in the natural environment, within the observed internal classrooms and external school sites.

Table 4.Parameter 2 – The Impact value (Source: Authors)

The impact value	The Child – Nature distance (C – N – D) ranges
IV = 1.00	On-site, within the studied space
IV = 0.75	within the school site boundary to the 50-meter distance
IV = 0.50	within the 50-meter to 70-meter distance

Parameter 3 – The Naturalness of Looking/ Hearing/ Touching/ Smelling/ Tasting

The initial step in the analyse process for each sense is to create a land cover plan to define the value of naturalness in a school site and the 100-meter urban setting. Additionally, under the impact ratios which affect the level of a child’s visual and non-visual experiences, a grid-system is attached to the land cover plan. This grid-system is modified in the combination of four sub-grid types which are overlaid to the plan: (**IV**=1.00) on-site: no-grid, all elements of built and natural environments are coloured representing the relative land classification with the real value of boundary and size; (**IV**=0.75): a 2.5m x 2.5m grid; (**IV**=0.50): a 5.0m x 5.0m; and (**IV**=0.25): a 10.0m x 10.0m grid.

Distinctly, *Naturalness value (NV)* of Built environment’s classes ranges from 0.00 to 0.75 in corresponding with the percentage of constructed materials, and all the classes of natural environments account at 1.00. Thus, these values range between 0.00 and 1.00, where 0.00 is the highest ratio in the built environment of total surface area, and 1.00 is associated with an entire Nature. In the specific case of the classroom, there is an addition of an ‘indoor landscape’ item in an ‘on-site’ grid to determine the indoor natural elements which are designed and fixed, e.g. the vertical green wall, the indoor plant area. Next, the examination process for Naturalness of visual and non-visual experiences is established and shown in Table 5. The *Naturalness of Hearing (NoH)*, *Touching (NoTo)*, *Tasting (NoTa)* and *Smelling (NoSm)* are identically quantified with the similar parameter in the Permeable Surface Area. Due to the ‘directional’ feature, the *Naturalness of Vision (NoL)* is distinctly figured with the different method in determining the Permeable surface area of vision by DepthMapx-0.50 software.

Table 5. Parameter 3 - The Naturalness of Looking, Hearing, Touching, Tasting and Smelling (Source: Authors)

Labels	<p>NoX (NoL*, NoH, NoTo, NoTa, NoSm): Naturalness of Looking, Hearing, Touching, Tasting, Smelling</p> <p>No_x_{class}: Naturalness of (X) according to the seperated land cover class</p> <p>NV_{class}: the Naturalness value of class</p> <p>IV_{grid}: the Impact value of the studied grid</p>
Equations	$\text{NoX} = \sum (\text{Nox}_{class} \times \text{NV}_{class})$ $\text{Nox}_{class} = \sum \frac{\text{Permeable Surface area of class within a particular gird} \times (\text{IV}_{grid})}{\text{Total of Permeable surface area}}$
Obtained results	NoL* ; NoH = NoTo = NoTa = NoSm

* In particular, the **No_L** value of **NoL** is calculated by the following method.

- Firstly, architectural drawings of the studied spaces are made ready to examine the visual field with children’s sitting and standing eye-heights (according to children’s anthropometric dimension data for each region), and then imported to DepthMapX.
- The DepthMapX version 0.50 is used to explore the visible area of observed points within the studied environment.
- The results were exported to calculate the visible permeable surface area. In the AutoCAD interface, Permeable Surface area of classification within particular grid-system was measured, and the Total of Permeable surface area was defined as the sum of visible area within the boundary of visibility graph.
- Next, using Microsoft Excel, the parameter as **No_L** (Naturalness of Looking of each land cover class) were used to calculate the **NoL** as above equations.
- The process continued with other points (the distance between points from 1.2m to 3.0m in indoor spaces), then the average values of observed points within indoor spaces (classrooms) and points at playgrounds were given as the parameter to calculate the **NoL** value for the corresponding place.

The Total Value of Naturalness (VN)

With three framed parameter systems, the *Total Value of Naturalness (VN)* of the observed space is defined as:

(VN): The Total Value of Naturalness

(NVOL), (NVOH), (NVOTO), (NVOTA), (NVOSM): Naturalness value of Looking, Hearing, Touching, Tasting and Smelling

$$VN = NVOL + NVOH + NVOTO + NVOTA + NVOSM$$

In particular,

$$\begin{aligned} NVOL &= PV \times NoL \\ NVOH &= PNI \times NoH \\ NVOTO &= PC \times NoTo \\ NVOTA &= PC \times NoTa \\ NVOSM &= PC \times NoSm \end{aligned}$$

The value of each sense ranges from 0.000 to 1.000, where 0.000 is no connection to Nature and 1.000 is a entire connection to Nature; it means *Total Value of Naturalness (VN)* ranges from 0.000 to 5.000. The higher the value (VN) obtains, the more closely the children in this space (classroom or playground) experience the natural environment via their senses. Besides, the sub-values (**NVOL, NVOH, Nvoto, NVOTA, NVOSM**) also reflect the different levels of a child directly integrate with Nature via each sense in consideration of which sense obtains the highest, medium and lowest values that could contribute to appropriate design proposals for a multi-sensorial natural experiencing.

ANALYSIS AND INTERPRETATION

Following the established method, the process of data analysis was applied to primary school spaces to calculate the permeable range, the naturalness value of each sense and the total amount of naturalness which pupils could directly connect within their own spaces.

The Permeability value

Through site studies and the architectural drawings, the plans and sections of classrooms are defined to calculate the permeable areas, and then to explore the permeability values of the relative architectural features which are presented in Table 6. Particularly, the connective figures of classrooms were reflected the evident conditions of children and teachers' studying activities. In the cases of classrooms TGA_K_P7 and TGA_M_P3.4 and TGA_N_P3.4, the values of connectivity (PC) account 0.000 because windows and doors were mostly closed during studying hours, they are used only for lighting purpose. All outdoor places where children play during intervals and have outdoor-classes have (1.000, 1.000, 1.000) of the total permeability values because these areas are totally connected with surrounding nearby natural environments.

Table 6. The permeability values of TGA classrooms and playgrounds (Source: Authors)

Places	ID	Total Permeability		
		Noise insulation (PNI)	Connectivity (PC)	Visibility (PV)
Indoor spaces - Classrooms	TGA_K_P7	0.044	0.000	0.052
	TGA_K_P4	0.090	0.164	0.164
	TGA_K_P3	0.088	0.162	0.162
	TGA_M_P3&4	0.018	0.000	0.044
	TGA_N_P3&4	0.047	0.000	0.087
Outdoor spaces – Playgrounds	TGA_K_O			
	TGA_M_O1		1.000	
	TGA_M_O2			
	TGA_M_O3			
	TGA_N_O			

The Naturalness of Looking, Hearing, Touching, Tasting and Smelling

In order to define the Naturalness of five senses, the initial step is creating the land coverage plan with the relative grid-system of three TGA schools which was originated in these documentations: (1) **NLUD 4.4 Land Cover** (Harrison, 2006) that provides the land cover nomenclature; (2) **LCM2015 (Land Cover Map 2015 Dataset Documentation (Version 1.2, 22nd May 2017), 2015)** which provided a parcel-based land cover map

for the UK; and (3) **LCS88** (*The Land Cover of Scotland 1988 Final Report*, 1993). Synthetically, the Description of Land Coverage which is derived from given sources are developed and modified for the Naturalness value in the context of the particular buildings and its surrounding spatial environments. The layers of Built Environment are included Permanent made surfaces, Building and Structures and General land surfaces with 4 sub-classes (viz., High intensity and Bare surface, Medium intensity, Low intensity, and Open space) which are classified accordingly the ratio of constructed materials cover of the total surface area. The layers of Natural environment are Cropped land, Grass, Woodland, Shrub, Heathland and Bog, Inland rock, Water, Coastal features. Distinctly, Naturalness value of Built environment's classes ranges from 0.00 to 0.75, and all the classes of Natural environments account for the Naturalness value at 1.00. The detailed description with coloured keys is shown in the Figure 2.

Overall, it is clear that three similar scaled land cover and grid-system plans show distinct variations in the school areas and the diversity of the schools' surrounding environments (Figure 2). The total covering area within 100-meter distances and the ratios between built and natural environments of schools' covering permeable areas are shown in Table 7. TGA_Kelvinbridge heads the table for the largest total covering permeable area. The figures for natural area coverage and ratio of the natural environment for TGA_Newlands are significantly lower than the other schools with about 8500 square meters, a 24.2% of school covering permeable area. This proportion is similar in TGA_Kelvinbridge site (at 25.5%) although this site has much higher natural area coverage with around 26,000 square meters. In contrast, only TGA_Milngavie school site has the natural proportion higher than built environment (with 52%) and also accounts for the largest number in term of permeable natural environment – about 37,800 square meters; this value is approximate 1.5 times and 4.5 times higher than that of TGA_Kelvinbridge and TGA_Newlands respectively. Additionally, in term of natural diversity, TGA_Kelvinbridge and TGA_Milngavie have a greater mixture of natural environments which are surrounded by substantial woodland and water areas with associated vegetation systems. In conclusion, TGA_Milngavie has the most favourable conditions for a general assessment of natural environment of a school site, while the school site of TGA_Newlands is considered as the poorest natural environment both in qualitative and quantitative terms.

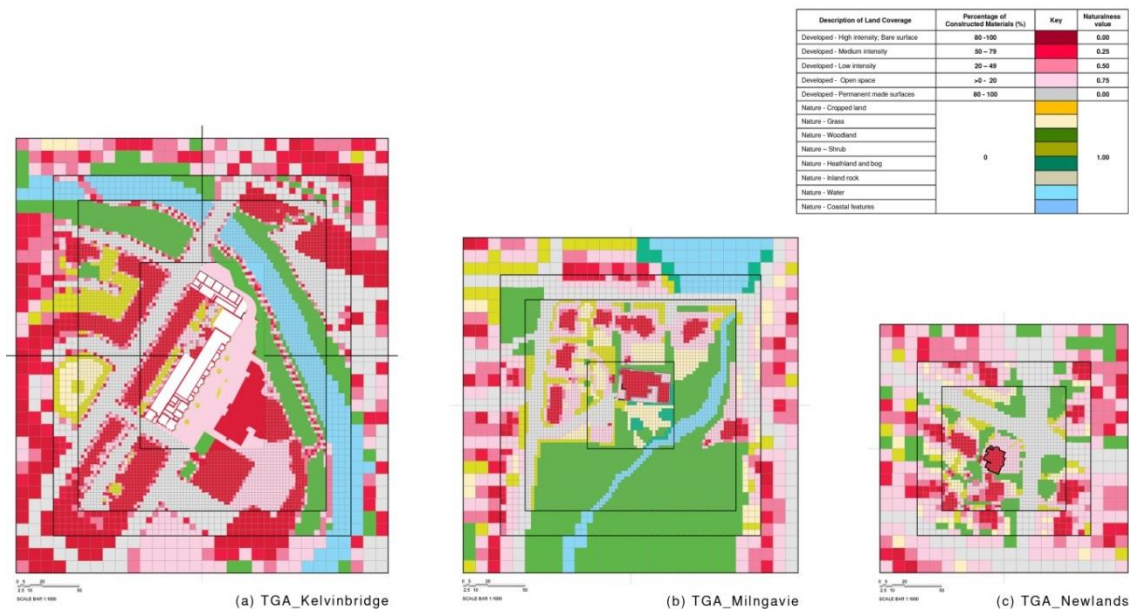


Figure 2.The Land cover and grid-system plan of TGA primary schools (in equivalent scales) (Source: Authors)

Table 7.The features of covering area within a distance of experience of TGA primary schools (Source: Authors)

ID	Total Covering Area	Covering permeable area	Built Environment	Natural Environment

	(sqm)	(sqm)	(sqm)	(%)	(sqm)	(%)
TGA_K_O	105000.00	102372.45	76301.83	74.5%	26070.62	25.5%
TGA_M_O1	72900.00	72777.71	34969.48	48.0%	37808.23	52.0%
TGA_M_O2	72900.00	72777.71	34969.48	48.0%	37808.23	52.0%
TGA_M_O3	72900.00	72916.70	35108.47	48.1%	37808.23	51.9%
TGA_N_O	40000.00	35298.32	26767.11	75.8%	8531.21	24.2%

The Naturalness of Looking

The values of (NoL) are evaluated in the context of each classroom and playground through the comparison of observed points to explore the correlations between the architectural features of envelopes, the fields of view-points and the positions of interior layouts relating to activities of children. The results obtained are represented in Figure 3 and Table 8.

In TGA_Kelvinbridge, it is evident that the visible area and the amount of nature for the vision of class K_P7 thoroughly differ to the classes of P3 and P4. There is only one point (K_7.5) which has a view of a small proportion of Nature (4%), whereas other points are 100% of the built environment. These figures significantly reflect the current condition of this room where windows are directly opened to the street and an adjacent 4-storey building presents a visual barrier in front of two windows; it is also affected by the lowest value of surrounding naturalness. Classrooms P3 (at first floor) and P4 (at second floor) have almost similar entire visible areas, much higher than P7 room, and their ratios of natural environment are between 16% and 32%. These results are associated with their closely similar positions in the school master planning and the height level change within 1 storey. In the case of outdoor playgrounds, there are two point-groups with considerable divergent values. At points K_O.4, O.5, and O.6 which have the rounded buildings as visual barriers, they account only about half figures in comparison with points O.1, O.2, and O.3 consisting direct eye-sights forwarding to the woodland and water lands in terms of visible areas and the higher percentages of Nature. However, due to the impacts of high density in this urban environment, these outdoor view-points account for built-natural proportions in a range between 12% and 32%.

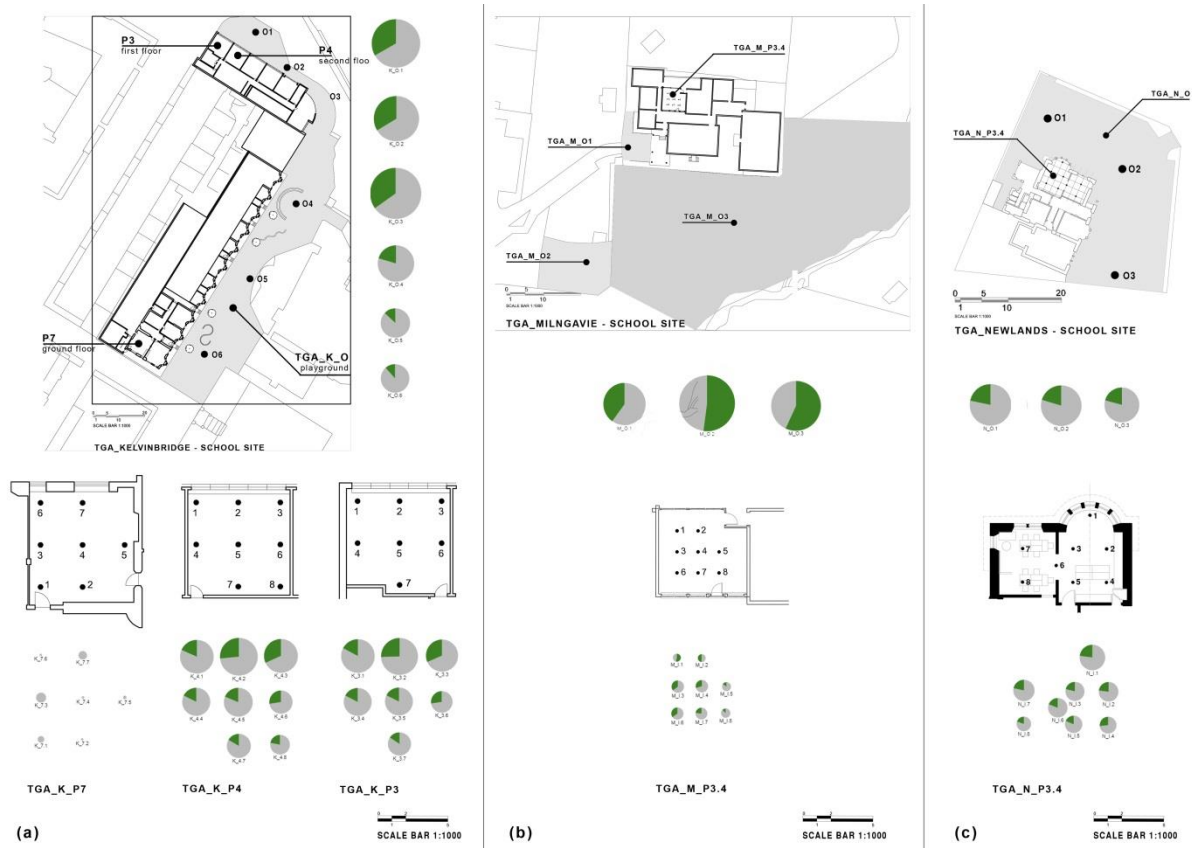


Figure 3. The visible areas and ratios of Built - Natural environment of observed view-points (the scales of bubbles illustrate the relative amounts of natural visible areas); (a) TGA_Kelvinbridge; (b) TGA_Milngavie; (c) TGA_Newlands (Source: Authors)

At TGA_Milngavie, the specific location of the classroom is within the main building. In particular, this room has large area of glass-windows at the side which is connected via an open-viewed corridor adjacent to an external landscaped area – bushes and wooden plants as hedgerow (Figure 2.b). However, the glass area is above the children’s sitting and standing eye-heights (according to children’s anthropometric dimension data of British from 6 to 12 years old (Pheasant and Haslegrave, 2006, pp. 267–276) for case studies in Scotland and UK). At the side of the main door, there is a band of transom windows for natural lighting only. Its visible area is much lower than the classrooms K_P3 and K_P4, although it is three times higher than K_P7 room. Furthermore, the results also show that positions closer to the high-windows, show decreased visible areas. All view-points at the three playground areas demonstrate significant values of connection with Nature via looking according to the highest values in terms of visual area and the proportion of Nature (above 50% in average).

Due to the limitations of school size, the total visible area of the TGA_Newlands is mostly affected by outdoor views. The observed classroom has many advantages with two sides connecting directly to the outdoor environment through large glass-window systems at appropriate heights. Thus, these figures reflect the considerable area of vision. In addition, children have larger view-fields when they sit or stand more closely to these openings. Nevertheless, when we take into account the impact of the land coverage features in relation to the urban setting, the value of Nature for these views is approximate 20% of the total area.

Table 8. Figures of Total visible area and the Built-Natural proportion of observed points in classrooms and playgrounds (Source: Authors)

Place. Point	Total Visible Area	Built Environment	Natural Environment	Place. Point	Total Visible Area	Built Environment	Natural Environment
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	High intensity	Medium intensity	Low intensity	Open space Multiple surface								NoH NoTo NoTa NoSm
	0.00	0.25	0.50	0.75								
TGA_K_7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TGA_K_4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TGA_K_3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TGA_M_P3&4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TGA_N_P3&4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TGA_K_O	0.000	0.009	0.018	0.047	0.000	0.001	0.096	0.034	0.013	0.144		0.219
TGA_M_O1	0.000	0.003	0.011	0.065	0.000	0.000	0.192	0.051	0.040	0.283		0.362
TGA_M_O2	0.000	0.003	0.011	0.064	0.000	0.000	0.192	0.051	0.040	0.283		0.361
TGA_M_O3	0.000	0.003	0.011	0.065	0.000	0.027	0.171	0.051	0.040	0.290		0.368
TGA_N_O	0.000	0.006	0.020	0.091	0.000	0.007	0.066	0.028	0.016	0.117		0.234

The Total value of Naturalness (VN)

Finally, the results of TGA pre-schools as the case studies of this approach method for Naturalness values of space are given in the Table 10 and Figure 4.

Regarding the external spaces of these schools, it can be inferred that the playgrounds of Milngavie offer the most substantial multi-sensorial natural environment. These spaces also provide children with a comprehensive 'real' experience of Nature where they are exposed via visual and non-visual senses, to the highest level of naturalness available and a wider range of Nature's values. However, the figures of M_O3 (wild area) are fairly insignificant in comparison with the two other spaces in Milngavie since the size is relative small in total, covering an area within 100m distance although it is classified as entire nature (Naturalness value = 1.00) and in on-site distance (Impact value = 1.00). Fewer natural connections occur in both the TGA_Kelvinbridge and TGA_Newlands playgrounds. These sites have approximate average values of naturalness in five sensorial-dynamics, but these are slightly lower in the figure of Looking while slightly higher regarding touch, hear, smell, and taste in the Newlands case.

When considering internal spaces, the classrooms K_P3 and K_P4 exhibit the highest values of Nature for all five sensorial modalities while children in other classes have less direct connections with Nature in terms looking and hearing. The principal reason for this difference lies in the location of these rooms within the school and in part because of the features of windows. In the layout of entire school master plan, these particular rooms provide direct views of a rich external natural environment; (thus higher values of Nature for looking) and, since they were often open during the observation period, enhanced opportunities for non-visual sensorial connections were also provided. Furthermore, the size, height, and style of windows, and their position on two walls of the classroom increased the direct connected with Nature and helped to "*bring nature closer to children*". In contrast, within the same school, the K_P7 classroom exhibited reduced ranges of natural connections due to an unfavorable location (outlook), and because windows were closed during the observation period. Generally, the indoor places in Milngavie and Newlands have similarly distinctive features. Although the school Milngavie provides a strong 'Nature-at-the-doorstep' context, the potential experience from the classroom was limited by its location within the building layout and was negatively impacted by window's forms and positions. Conversely, the results for the Newlands P3.4 room, which has direct connection with outdoor spaces through a better building layout and considerable size of windows, is lacking for the senses of smelling, tasting and touching since the window was required to be closed for noise insulation purposes relating to an adjacent crossroads. Thus, it reflects the unfavourable impacts of the built-natural environment in an urban configuration.

Table 10.Total value of Naturalness (VN) of Child’s Visual and Non-visual experiences (Source: Authors)

ID	Total Permeability			Naturalness of sense					Natural value of sense					Total value of NATURALNESS
	Noise insulation	Connective	Visibility	Looking	Hearing	Touching	Tasting	Smelling	Looking	Hearing	Touching	Tasting	Smelling	
	PNI	PC	PV	NoL	NoH	NoTo	NoTa	NoSm	NVoL	NVoH	NVoTo	NVoTa	NVoSm	VN
TGA_K_P7	0.044	0.000	0.052	0.120	0.219	0.219	0.219	0.219	0.006	0.010	0.000	0.000	0.000	0.016
TGA_K_P4	0.090	0.164	0.164	0.209	0.219	0.219	0.219	0.219	0.034	0.020	0.036	0.036	0.036	0.162
TGA_K_P3	0.088	0.162	0.162	0.205	0.219	0.219	0.219	0.219	0.033	0.019	0.035	0.035	0.035	0.159
TGA_M_P3&4	0.018	0.000	0.044	0.461	0.364	0.364	0.364	0.364	0.020	0.007	0.000	0.000	0.000	0.027
TGA_N_P3&4	0.047	0.000	0.087	0.219	0.234	0.234	0.234	0.234	0.019	0.011	0.000	0.000	0.000	0.030
TGA_K_O	1.000	1.000	1.000	0.283	0.219	0.219	0.219	0.219	0.283	0.219	0.219	0.219	0.219	1.159
TGA_M_O1	1.000	1.000	1.000	0.324	0.362	0.362	0.362	0.362	0.324	0.362	0.362	0.362	0.362	1.771
TGA_M_O2	1.000	1.000	1.000	0.365	0.361	0.361	0.361	0.361	0.365	0.361	0.361	0.361	0.361	1.810
TGA_M_O3	1.000	1.000	1.000	0.392	0.368	0.368	0.368	0.368	0.392	0.368	0.368	0.368	0.368	1.866
TGA_N_O	1.000	1.000	1.000	0.230	0.234	0.234	0.234	0.234	0.230	0.234	0.234	0.234	0.234	1.166

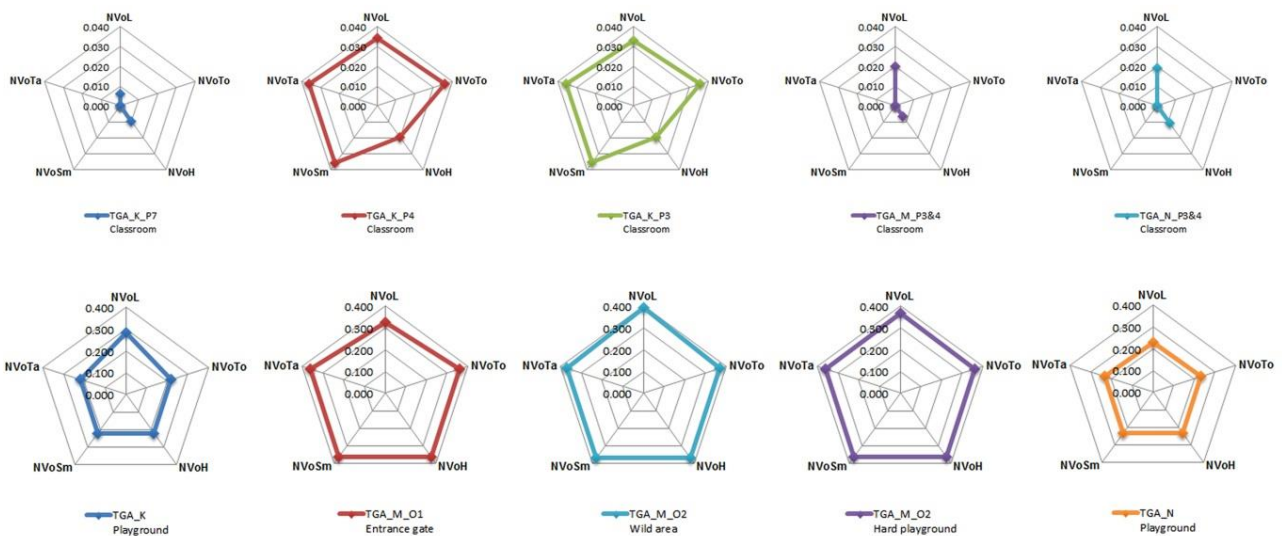


Figure 4.The Naturalness value of Visual and Non-visual senses within the classrooms and playground areas of three TGA primary schools (Source: Authors)

CONCLUDING REMARKS

Through the application of developed method to three case studies at TGA primary schools in Glasgow, it is suggested that the values of multi-sensorial experience of Nature, as they relate to space, significantly depend on particular design characteristics within urban settings, and are impacted by planning decisions on the built environment, and by a variety of architectural elements and interior features. In particular, all sensorial modalities are significantly associated with attributes of nearby natural environments, and both in

terms of scale and quality are dependent on the distance ranges of the child's sensorial experience. While the sense of vision is affected by the visibility of envelopes and the observer's positions within the spatial environment, the direct natural connections via the senses of hearing, touching, tasting and smelling are associated with the connectivity level of envelope features. Improvements in primary school architectural environments can be achieved through a consideration of the distance ranges of a child's sensorial experience and designing with children's visual and non-visual experiences of Nature in mind. The visual connectivity of a classroom can be improved by analyzing visible areas of identified view-points, through selecting appropriate seating arrangements, identifying specific areas for the teacher, and by selecting classroom furniture. In the case of a classroom which lacks direct natural connections due to its location and nearby urban environment, its primary function could be designated to other activities or features and openings could be renovated. In terms of outdoor spaces for children's restorative experiences, under the impact value of distance, landscape reconstructions can be designed to increase the naturalness values within the school's boundary, and areas with the greatest potential for multi-sensorial exposure natural environment can be identified for the pupils' daily activities, such as outdoor classes or interval sections. These spatial decisions at a micro level can directly transform opportunities for children's experience of the natural environment around them with meaningful outcomes. In the conceptual design process, the approach can also support decision-making by examining the value of naturalness of a school site within an urban context to inform appropriate urban planning and development decisions involving proposals for new schools at the macro level.

In summary, this study has developed and applied a method to examine relationships between the direct level of Child-Nature direct connection via sensorial modalities and primary school spaces (indoor and outdoor) within the context of urban and architectural decision-making. The methodology is proposed to help understand 'real' natural value, dependent upon, not only various factors of the biological characteristics, culture, ethnic and individual experiences, but across varying C-N-D ranges and taking account of the impacts of spatial environmental properties within urban settings. The methodology for measuring visual and non-visual sensorial experiences of Nature, and its application to children's learning and leisure spaces within primary school architecture could offer a tool for assessing current schools, and evaluating future design proposals for new schools. Moreover, apart from primary school architecture for children, this methodology could be fully developed to the comprehensive Human-Nature relationship under the impacts of physical features and societal of other diversified environments in a future study. However, the offering reasonable primary school architecture for a proper children's multi-sensorial experience with natural environment cannot thoroughly established with a quantitative aspect by the present study only. More qualitative research is recommended to examine the process of altering from "cause" to "perceived" Nature of users' cognitions, attitudes and behaviours within the exposure proximity to Nature.

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