SCRI Research Report 2

Optimal Learning Spaces
Design Implications for Primary Schools

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Optimal Learning Spaces

Design Implications for Primary Schools

Professor Peter Barrett

Professor Peter Barrett is President of the UN-established International Council for Research and Innovation in Building and Construction (CIB) involving 2000 experts in 60 countries. He is currently Chairman of Salford Centre for Research and Innovation (SCRI) and a member of the UK National Platform for Construction and of the European Construction Technology Platform. He has produced over one hundred and seventy single volume publications, refereed papers and reports, and has made over one hundred and ten presentations in around sixteen countries. Peter has been leading the CIB initiative on Revaluing Construction for some years and part of this concerns better understanding how value from the built environment is gained by those in society. This has led to work in the area of Senses, Brain and Spaces, ie how spaces are experienced by people through their senses and interpreted by their brains. The practical application of this interest has been around school buildings and in particular how to create "optimal learning spaces".

Dr. Yufan Zhang

Dr Yufan Zhang is an architect. She carried out her PhD in the School of Architecture, University of Sheffield. Her PhD work was focused on occupants' comfort and behaviour and how they use environmental control strategies to modify their internal environment. In January 2008, she joined SCRI as a Research Fellow. Yufan's work in SCRI is to conduct research on a variety of issues related to 'realising value in use' of the built environment. This involves the identification of international good practice, linking this to evidence from applied activities, such as the post occupant evaluations, in order to develop a stronger evidence base to better understand the characteristics of beneficial spaces for users, especially in the design and refurbishment of schools.

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Foreword

Considerable evidence shows that there is an explicit relationship between the physical characteristics of school buildings, and the spaces within them, and educational outcomes. Poor school conditions make it more difficult for teachers to teach and pupils to learn. Every effort should therefore be made in the design stage to create the ideal conditions for learning to take place. However, a variety of teachers with specific and very different groups of pupils will subsequently inhabit and inherit these spaces. Each teacher and each group of pupils is different, and teachers must develop the generalized environment for specific purposes and groups. When a new building is complete and is handed over to the teachers, the school can only be a "finished beginning" in which adaptations will occur. Only when spaces are seen to support learning and create a positive experience, can we say it was designed successfully.

To achieve optimal design solutions is a complex and challenging goal. This report seeks to frame the multitude of opportunities within just a few major design principles derived from the basics of how people experience spaces in response to the environmental data they gain through their senses and synthesise in their brains. This leads to a focus on naturalness, individualisation and level of stimulation. The resulting practical opportunities have been illustrated / evidenced with case studies and we hope that this material will stimulate significant thought and experimentation about school design amongst clients and designers alike.

The suggested approach is not just another word for design standards. This SCRI report – and the others in the series on Optimal Learning Spaces for schools (OLS) – aims to help schools to create learning environments that are more effective and comfortable. Developed through extensive research into international best practice, in consultation with experts and sector representatives, it provides in-depth and practical suggestions for improving the quality of the internal and external learning environment so ensuring that pupils and teaching staff enjoy effective communication in comfortable spaces.

However, we consider this to be work in progress. This report brings together a range of design opportunities. The next stage will be to explore the practical interactions between the design parameters. This is an exciting opportunity for us all, and we look forward to receiving any feedback you may care to give us. Contact details are given on the inside of the front cover.

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1 Introduction

Following Manchester City Council's (MCC) involvement in SCRI's Senses, Brain and Spaces workshop in March 2007, it became evident that there is potential in investigating the possibility of infusing the design, construction and use of new / refurbished schools with insights from scientific knowledge of the sensory impacts of spaces, including to some degree how they are mediated by neurological processes. From this starting point, a research activity entitled 'Optimal Learning Spaces' (OLS) has been developed in conjunction with MCC. This project focuses on teaching and learning environments at the micro-level, rather than on educational policies, management or organizational structures. There are two elements to this project whose aim is to develop an evidence base for what constitutes an optimal learning space through:

- A thorough exploration and synthesis of the international literature on design issues related to schools with particular regard to the sensory impacts of spatial variables on the learning process. Our progress so far on this will be available as a separate SCRI report.

- Direct liaison and discussion with the potential and actual users of the school, as appropriate, in order to increase our understanding of how to realise the full potential of the spaces provided. This is largely informed by the conduct of post occupancy evaluation (POE) surveys of new and existing schools. The outputs of these POEs will be summarised as a separate SCRI report.

In the UK Government's Building Bulletin 95, generic plan types are proposed for primary and secondary schools. They help to rationalise the various strategic approaches in a systematic way, which is easy to communicate at an early stage of the design. However, the emphasis is very much on sustainability, flexibility, adaptability, community engagement and value for money. There is a focus on issues of space efficiency and future proofing designs. Building from this position, and informed by the above SCRI sources, this report seeks to complement this guidance by bringing out the design implications of an emphasis on the needs of children and educators, stressing how spaces can positively support core teaching and learning activities.

The aim is to link scientific knowledge to case-study examples of real schools that have recently been built, in order to provide a better understanding of how to create outstanding, fit for purpose and friendly environments for pupils and teaching staff alike, while ensuring that they also enjoy comfortable communication and a productive school life.

The whole project is based on a fundamental belief that school planning and design can play an important role in enhancing teaching and learning outcomes by creating better built environments. The specific aims of this report are that all those involved with primary schools, from heads and designers to local-authority building officers, will be better informed in their decision making by:

- An analysis and synthesise into a relatively simple structure of current international research findings on learning and teaching, environments (summarised from the separate SCRI report);

- The identification and analysis of case examples of innovative learning environments from all over the world;

- Guidance on how schools can make the best use of the design options available; and

- Supporting what schools and local authorities can do to ensure that the investment of capital funding is used as effectively as possible.

This report concentrates on mainstream primary schools, although nursery and kindergarten examples are used where relevant to highlight design approaches. The report is divided into four sections. It begins with an Introduction that presents the background about this project. The foundations are discussed in the second section, which identifies the study procedure. The third part looks at the issues to address the specific design strategies of schools – using the lessons from various case studies to highlight what to consider and what to avoid. A number of recent case studies from around the world are used throughout this section related to specific points – those with supporting evidence of impacts are termed "confirmatory cases", whilst those without have been called "illustrative cases". The final part summarises the practical suggestions drawn from this study and also introduces the work which should be carried out in the near future.

2 Foundations of the Design Implications

Whilst there is no universal best school environment, general principles of how physical spaces can support teaching and learning unquestionably exist. The literature review and post-occupancy evaluation conducted in the first phase of SCRI's OLS research have provided the foundation of this document. By synthesising these studies it has been possible to suggest new design paradigms for primary schools. As in any building design, there needs to be a balance between perceiving the whole and breaking the whole down into parts that are easily understood and negotiated. One has to look at designing from both the inside out and from the outside in, all for a variety of users. Pupils are at the centre of learning, so their needs should be at the heart of a learning-centred design process.

2.1 Literature Review

When looking at the literature, a great number of innovative educational initiatives can be found all around the world. We all know that bright, quiet, warm, safe, clean, comfortable and healthy environments are an important component of successful teaching and learning. A growing body of research addresses the complexities lying behind this perspective. Some of it is good; some less so; much of it is inconclusive. The literature review aimed to examine the available evidence of how building design can help schools to create and improve learning environments that are appropriate for current and future educational needs. It explored the impact of learning environments on pupils' achievement, engagement, affective stage, attendance and well being. The findings provide a rich source of ideas on improving the quality of the learning environment, so ensuring that pupils and teachers enjoy comfortable communication and a more efficient learning space.

2.2 Post-occupancy Evaluation

Working with a major UK local authority (MCC) five post-occupancy evaluations of well-regarded primary schools were carried out between February and July 2008. The main purpose was to provide feedback on generic and specific success factors for the design, operation and use of buildings, together with areas of difficulty that require further investigation. Secondly, the study aimed to investigate the potential of using post-occupancy evaluation as a useful toolkit for good practice guidance and as a routine quality assurance measure for the building industry. In addition, as the occupants of all investigated schools took ownership of the design process up to a certain level, the study also attempted to compare the impact of design on the performance of the school in terms of factors such as its flexibility, size, furniture settings, lighting, acoustics, air quality and satisfaction level.

2.3 Principles

The principles that underpin this report have developed from SCRI's Senses, Brain and Spaces (SBS) research work. Certain of these principles suggest direct connections between sensory stimulations, learning and physical space. The explanation for this would seem to rest on research evidence concerning human sense perception, impacts and the underlying cognitive calculations involved. It is suggested that three design principles emerge to support application in practice: the role of naturalness, the opportunity for individualisation and appropriate levels of stimulation. These are justified a bit more at the start of each of the relevant sections in the next part of the report, however, it can be said:

- ➔ *Naturalness* – humans have basic requirements derived from our basic needs for light, air and safety. These are hard-wired into our brains and create a strong response to natural elements in our environment that we intuitively feel to be nurturing and sustaining.

- ➔ *Individualisation* – however, each brain is uniquely organized. We all perceive the world in different ways and act accordingly. Thus, people do not necessarily respond to the same environmental stimulus in the same way. The best opportunity for success comes from some level of variety flexibility and choice.

- ➔ *Appropriate level of stimulation* – learning involves both focused attention and peripheral perception. While space should not distract from the ability to focus, it can provide sensory stimulation that influences the experience and thus learning. Space can also be the 'silent curriculum' that complements and increases engagement (Taylor 2005).

These three themes become basic principles that can and should inform school design. They are each informed by a variety of design parameters, which in turn connect to practical options. An indication of the rich connections between these parts is summarised in Table 1. The three main principles and their associated design parameters that make up the x-axis provide the structure for Section 3 of this report.

Table 1: Design principles and practical options - cross referenced to sections in report

(Pullouts give some examples.)

Practical options		Light	Sound	Temperature	Air quality	Choice	Flexibility	Connection	Complexity	Colour	Texture
		Naturalness				**Individualisation**			**Level of stimuation**		
Plan & envelope	Location	3.1.1	3.1.2					3.2.3			
Plan & envelope	Orientation	3.1.1		3.1.3	3.1.4						
Plan & envelope	Layout		3.1.2	3.1.3	3.1.4						
Plan & envelope	Apearance								3.3.1	3.3.1	
Plan & envelope	Windows	3.1.1		3.1.3	3.1.4	3.2.1					
Spaces	Rooms		3.1.2			3.2.1	3.2.2			3.3.2	
Spaces	Circulation							3.2.3		3.3.2	
Spaces	Outdoors										3.3.3

Design principles / Design parameters

Naturalness: The emotional systems have evolved over the millennia in response to the natural environment. Spatial configurations, light, noise, heat and air quality have been consistently proved to have a significant impact on students' academic achievement and ability to perform.

Individualisation: The brain function highlights the personal way in which individuals build connections between primary reinforcers and complex representations of secondary reinforcers.

Level of stimulation: Combinations of pleasantness and different levels of arousal yield either excitement or relaxation. When the level of stimulation is appropriate for given situations, certain reactions take place positively in the brain and mind, affecting mood, mental clarity and energy levels.

Site is away from the busy roads. Open areas and trees can be used as a buffer-zone to give acoustic separation.

The window is designed to allow ventilation options for varying conditions. The cafeteria is toward the leeward sides in order to minimise the kitchen and food smell spread into the whole building.

Ergonomics scales to the body of pupils, creating interesting and engaging spaces. it supports and interacts efficiently with the pupils' activity.

Layout with easily identifiable pathway improves the utilisation of spaces and helps keep the pupils orientated and stimulates their imaginations.

Soft elements, such as water, foliage are always welcomed to achieve pleasantness. It has positive effects on learning and cognitive qualities.

Windows can either be continuous from wall to wall, with the heads close to the ceiling in order to receive an amount of skylight and solar heat.

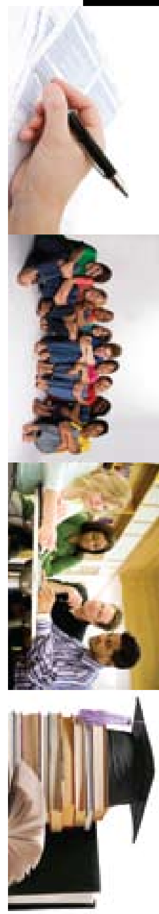
Absorbents on ceilings can reduce reverberation and can damp out the most annoying components of impact sound.Curtains and moveable screens with sound-absorbent surfaces can be used in order to change the sound characteristics of the area.

No obstruction outside is close to the glazing area; the main learning spaces are arranged to face between east and south, or west and south. a minimum of two hours duration of sun penetration should be guaranteed.

To maximise the flexibility of instructional clusters, it is very useful to provide a space especially for shared activity. The teachers can have break-out groups anytime as this space is always available.

School façade with diversity (novelty) catches the pupils' attention and arousal; and order (familiarity) helps the pupils make sense of it. A combination of order with moderate diversity can achieve pleasurable responses.

Pale or light green creates a passive effect that enhance quietness and concentration. Attention is directed inward with soft yellow, sandstone and pale gold.



3 Design Implications for Primary Schools

The following is a structured collection of aspects and principles derived from the literature review and from a wealth of school experience and reports. It invites an exploration of learning environments for their capacity to transform learning. Some of the ideas can apply to large-scale planning or single-classroom renovations. It primarily focuses on the places where teacher/pupil exchange happens, typically the classroom. The cases given may not be the most prototypical examples; however, they illustrate aspects of what optimal learning spaces can look like in practice. For each of the following sections, on naturalness, individualisation appropriate level of stimulation and their associated parameters, the argument behind the principle will be briefly given and then the evidence of positive / negative learning effects will be summarised against the various design parameters. From this basis the practical options that can impact through each of the design parameters will then be discussed in some detail including the use of relevant case studies.

3.1 Naturalness

As our emotional systems have evolved over the millennia in response to the natural environment, it does not seem unreasonable to suggest that our comfort is likely to be rooted in key dimensions of "naturalness" that should, therefore, infuse the design process. The stress here is, of course, on the positive aspects of naturalness, such as plenty of natural light, desirable temperature and clean air, etc. At the other extreme it is known that supernormal stimuli, such as the noise from man made artefacts, for example cars and construction works, can produce super-strong emotions because the stimuli are much more intense (unnatural) than those in which our present emotional systems evolved and that the subsequent responses are not necessarily adaptive (Rolls 2007, p450).

The emotional systems have evolved over the millennia in response to the natural environment. Spatial configurations, light, noise, heat and air quality have been consistently proved to have a significant impact on students' academic achievement and ability to perform.

Fundamentally, the human beings comfort in terms of 'naturalness' is affected primarily via the followings (Houghton 2009):

- ➔ Light: the sensation of daylight that supports visual comfort and facilitates visual performance.
- ➔ Sound: appropriate conditions for listening to wanted sound and not unwanted sound (noise);
- ➔ Temperature: maintaining the balance of heat gain and loss at a comfortable level;
- ➔ Air quality: removing humidity, artificial contaminants, odours and bacteria etc.

For schools, there is a growing body of work linking educational achievement and pupils' performance to the quality of 'naturalness' that exists in schools. The Heschong Mahone Group (1999) studied the impact of day lighting on learning in schools. They looked at 21,000 elementary school pupils and classified 2,000 classrooms for their day-lighting levels. They found positive correlations between the variables; that students progressed 20% faster in math and 26% faster in reading in those with the most daylight compared to those with the least.

Schneider comments that in general the research on effects of environmental noise is consistent and convincing: good acoustics are fundamental to good academic performance (2002, p6). Evan and Lepore (1993) have isolated the negative effect of noise on children's recall. They studied 1358 children aged 12-14 years in their own classrooms, using standard tests, but under different noise conditions. They then tested the pupils' recall a week later and found that a statistically significant decline in performance could be associated with the noise conditions.

Researchers have been studying the temperature range associated with better learning for several decades. Harner (1974) found that the best temperature range for learning reading and math is 20.0 to 23.3ºC. As temperature and humidity increase, students report greater discomfort, and their achievement and task-performance deteriorate as attention spans decrease (King and Marans 1979).

Most researches linking air quality to student performance depend on an association with increased student absenteeism. For example, Smedje and Norback (2001) found a positive relationship between airborne bacteria and mould and asthma in children, which in turn increased the absentee rate (also Rosen and Richardson, 1999).

The above studies are examples of solid evidence of the impact of aspects of naturalness on student per-

formance. The challenge is how to apply these findings holistically to achieve optimal design solutions. The following sections, therefore, focus on 'how' these benefits can be achieved through practical design options with case study examples.

3.1.1 Light

Good natural light helps to create a sense of physical and mental comfort, and its benefits seem to be more far-reaching than merely being an aid to sight. This owns in part to the soft and diffused quality of natural light, its subtle changing value and colour which electric lighting does not have. Low ceilings and deep classrooms can cause pupils to experience a gloomy feeling due to the disparity in light levels between the back of the room and the peripheral area near the window. Therefore, natural daylighting should always be the main source of lighting in schools, supplemented by electric light when daylight fades.

Overall, the essential requirements for the effective daylighting in schools can be summarized as follows:

- An adequate amount of light: The building is elongated along an East-West axis. Spaces, such as the library and art rooms, where only diffuse daylight is desirable, are located towards the North while the main learning and teaching activity areas can be to the South.

- A satisfactory distribution of the main components of light: Large windows and/or windows placed high in the wall such as clerestory windows optimise daylight distribution and bring light deeper into the space.

- The absence of glare: bringing daylight from two different directions reduces the chances of discomfort glare. Necessary shading control is needed and that can be easily adjusted by occupants.

Three practical options are addressed here.

➔ Orientation: this is mainly in regard to the sunpath. The learning spaces are so sited that a minimum of 2 hours duration of penetration is obtained.

➔ Windows: large windows with heads close to the ceiling are always desirable.

➔ Location: no obstruction is around because it may cast too much shadow in the daytime.

Orientation

For a school building, good lighting design, both natural and artificial is not only good from a quantitative point of view for the performance of certain visual tasks, but also from a qualitative point of view in that it provides a desirable and pleasant luminous environment.

The sky is the main contributor to the amount of natural light received within a space, thus the building's orientation is the most fundamental design choice for the control of daylight. The East and West sides receive sunlight for half of the day when the sun is in a low position. The rooms of the South façade can receive lighting by way of a combination of direct and diffuse light. The resulting soft shadows and shading allow for a vivid view of the three-dimensional qualities of the environment.

The North façade, although having relatively low illuminance, has the most constant and uniform daylight throughout the day and year, and therefore seldom experiences problems with glare discomfort for occupants (Burberry 1997).

Results from our post-occupancy evaluation surveys show consistent and convincing evidence that the occupants (staff and pupils) want as much natural light as possible and sunlight for as long as possible, even though this may cause problems such as overheating, glare and/or learning distraction. However, their experience is quite different from each other in terms of the sunlight received.

For example, Green End and Rolls Crescent are two primary schools, which have similar plans with the long axis towards the North and South. But their axes are twisted a little toward different orientations and Green End has a noticeable central atrium (Figure 1[1]).

These two design strategies lead to a great difference when it comes to how much sunlight they can receive. In Rolls Crescent, half the classrooms, such as those toward the Northeast, can receive less than 3 hours direct sunlight per day in summer. And in winter, the time is re-

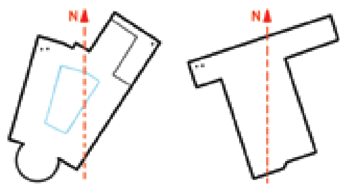


Figure 1: Building orientation of two primary schools in Manchester, UK; (Left) Green End Primary School; (Right) Rolls Crescent Primary School

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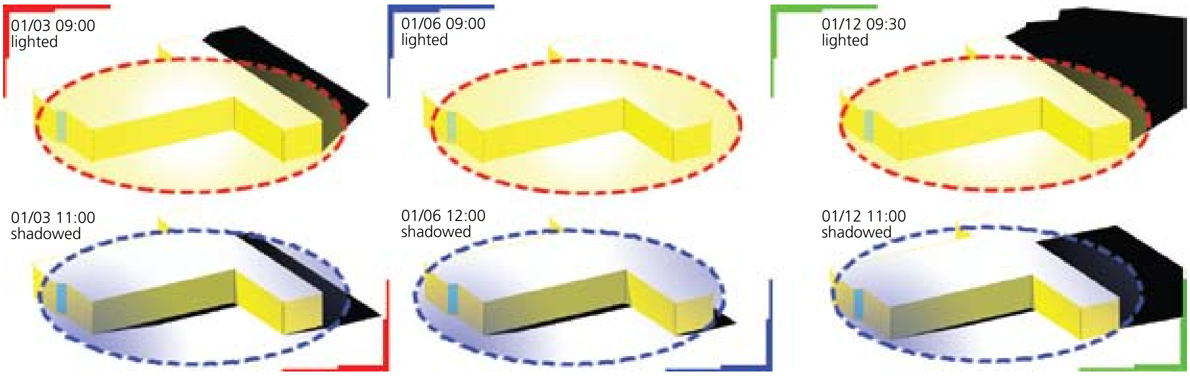


Figure 2: Classrooms toward the northeast: sunlight receiving in three seasonal days at Rolls Crescent (Confirmatory Case)

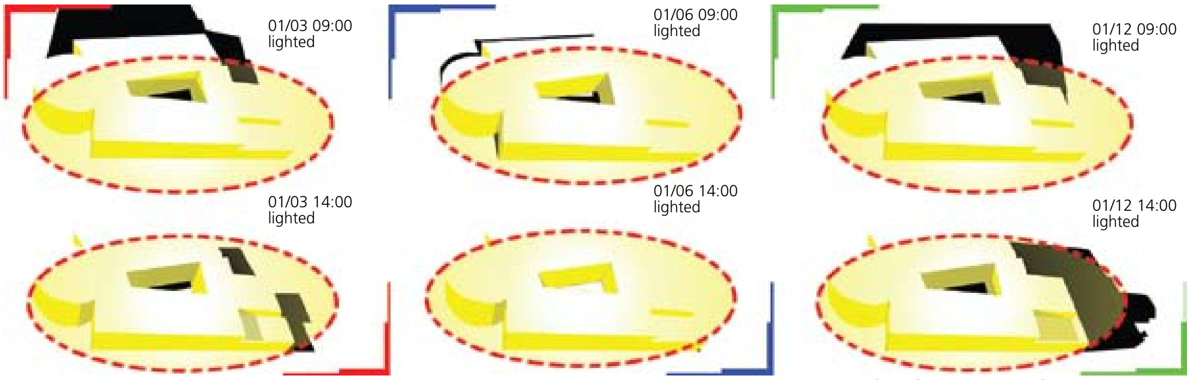


Figure 3: Classrooms toward the southeast: sunlight receiving in three seasonal days at Green End (Confirmatory Case)

duced to less than 2 hours. However, in Green End, even in winter they can receive more than 5 hours sunlight penetration. And also because of the atrium design, the classrooms at the other can enjoy the sunlight at the same time (Figure 2,3).

Windows

Once the building is erected, the amount of light that enters a space and the distribution within the space is mainly determined by overall glazing design factors, such as the numbers of windows, the size of glazed areas, their disposition and shape. With more windows in a room, the daylight will be more uniformly distributed in the space compared with a room that has just one single window. A glazing ratio (glazing area/wall area) of 40% is recommended for south, east and west facing windows, 55% is for north facing ones. Small windows at the top can allow air circulation, but not draughts (Burberry 1997).

The height of the window dictates to a great extent the effective depth of illumination with daylight. High windows tend to admit more useful daylight than low ones of the same size, as they offer the chance for the back of the room to be exposed to more sky. Effective illumination can be obtained into a room for a distance of as


Figure 4: Large windows are responded as one of the staff's favourite parts of the school. (St. Edward Primary School, Manchester, UK – Confirmatory Case)

much as 2.5 times the height of the window above the workplane. For example, for a classroom where the top of the window is 2 metres above desk height, the area that could be adequately daylit is up to 5 metres deep in from the window wall (Tregenza 1998).

Clerestory windows admit light deep towards the back of the room and hence create a more uniform daylight distribution throughout, especially if there is another side window. The relationship between illumination from the side and clerestory windows depends on their size, height and position. With a typical narrow window arrangement for clerestories, the recommended depth from the plane of the clerestory to the opposite wall is about equal to the distance from the mounting height of the clerestory above the work-plane level. For wider clerestories the depth could be one and half the mounting height. To obtain adequate and more uniform daylight distribution the height of the clerestory window should be about one half the sidewall window heights (Boubekri 2007) (Figure 5).

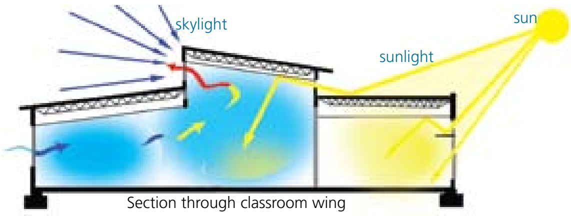


Figure 5: Daylighting concept

Ben Franklin Elementary School serves 450 pupils in kindergarten through grade six. Light is one of the great qualities, and it is used within the building as an important modulating device, integral to the perception of space. Extensive glazing connects the occupants with the outdoors. The spaces are oriented along an East-West axis, with glazing facing North and South to control and maximize the natural daylight within the building. Daylight modelling confirmed the appropriate configuration of windows and extent of shading devices to control glare and maintain diffuse, balanced daylight in all learning areas while providing carefully planned view windows. It floods through side windows, rooflights, direct and diffused, playfully reflecting off the coloured walls. The interior responds differently to bright sunny days and to overcast conditions (Figure 6).

Figure 6: (Left) The classroom and activity area with large glazing; (Right) The library utilizes clerestory windows for diffuse daylighting (Ben Franklin Elementary School, Kirkland Washington, US – Confirmatory Case) (Source: Mahlum Photography)

Location

The sky component and window glazing are generally the most significant issues that affect the luminous environment. But this is not always the case. When the window glazing is facing towards a building, the reflected daylight gained may still play a profound role and in some cases, can contribute up to nearly half the total internal illumination (Reid 1984, p144). Even so, except in high density urban areas, school locations without surrounding, obstructions, such as buildings and large trees, are recommended to avoid too much shadow in the daytime (Figure 7).

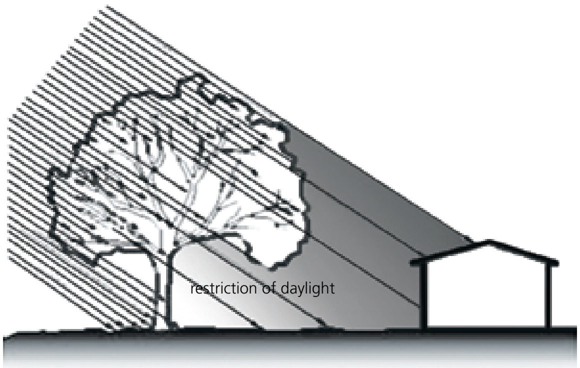


Figure 7: The amount of daylight is reduced greatly.

3.1.2 Sound

The subject of room acoustics is concerned with the control of sound within an enclosed space. The general aim is to provide good quality conditions for the production and the reception of desirable sounds. The quality of auditory perception and the control of noise are two principal aspects that determine the acoustic environment of a building. Comfortable and clear auditory perception, along with freedom from noise not only improves communication but also promotes working and learning efficiency. The converse is also true. For example, the improvements in achievement owing to good daylight found by the Heschong Mahone Group (see above) were cancelled out in a subsequent replication study (Heschong 2003) because of higher ambient noise levels.

The detailed acoustic requirements for a particular room depends upon the nature and the purpose of the space. However, the essential requirements for good acoustics in learning spaces can be summarized as follows:

- An acceptable noise level
- Adequate levels of sound
- Even distribution to all listeners in the room
- A suitable rate of sound delay for the type of room

Three practical options are addressed here.

➔ Location: school site is away from the busy road. At the same time, it also needs to keep a reasonable distance from the neighbourhood.

➔ Layout: the sensitive space can be carefully separated from the intruding noise. The toilets, storerooms and corridor can act as a buffer zone.

➔ Rooms: sound-absorbent surface can be used in order to change the sound characteristic of the space.

Location

Road, rail and air transport and industry are some of the main producers of noise, especially motor traffic. When the noise generated is an avoidable by-product, careful design and planning can eliminate, or at least reduce, the impact of noise on the built environment. Generally, the fundamental defence against the intrusion of noise lies in placing as much distance as possible between noise sources and the space where quiet is needed (Osbourn 1997, p49).

For example, there is a quite busy road in front of the

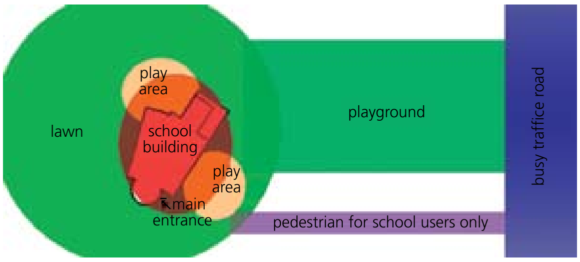


Figure 8: (Top) School and its surrounding; (Bottom) View from the busy road (Green End Primary School, Manchester, UK - Confirmatory Case)

Green End Primary School (Figure 8), Manchester, UK. Therefore, the building stands back around 30 metres away from the main road. A soft playground between them forms a barrier for considerably diminishing the intrusion of the noise. At the same time, the school site keeps a reasonable distance from the neighbourhood with grass and planting used as much as possible in order to minimize the negative impact of noise pollutants from all kinds of activities on the neighbouring properties.

Layout

The layout of rooms is an important aspect of the reduction of noise. Particularly sensitive spaces or rooms can be carefully located and separated from intruding noise both from the outdoors and from within the building. The more prominent sources of unwanted (for others) noise, such as music rooms, playrooms and/or mechanical service rooms within the building, should be identified. Then these can be located far away from the main spaces when the building is designed, special measures can be taken in order to enclose the noise produced, such as buffer zones, heavyweight walls and/or floating floors. For example, the toilet and corridor act as a buffer zone to give acoustic separation in Green End between classrooms (Figure 9). From the feedback of this school, the staff and pupils are very satisfied in terms of noise control.

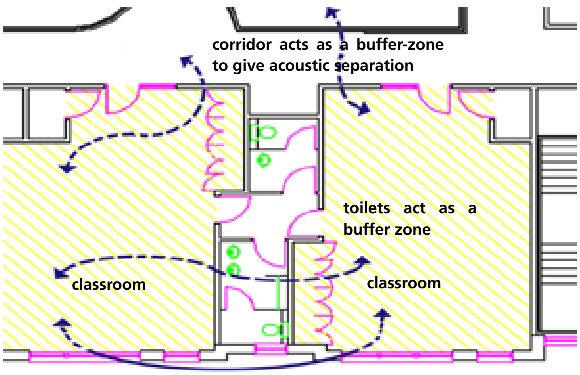


Figure 9: Use the toilet and corridor as buffers from the noise (Confirmatory Case)

Rooms

Absorbent materials are widely used on classroom ceilings which reduce reverberation and can damp out, to some extent, the most annoying components of impact sound (Figure 10). Normally, in a classroom of medium size and normal width and length, comfortable and clear auditory perception can be achieved without difficulty and without any special treatment of room surfaces because the sound can build up to a constant level throughout most of the room space except near the sound source.

However, when it comes to large rooms with multiple purposes, the situation becomes more complicated. For speech, the overall requirement for good reception is that it is intelligible, such as in meetings, drama sessions and lectures. This quality will depend upon the power and the clarity of the sounds in the range for human speech. However, the acoustic requirement for music performances is higher than for speech because music consists of a wider range of sound levels and frequencies which all need to be heard, full-toned, live and blended. The reverberation time (RT) is normally used to give a recommended and suggested criteria value in a space. Normal speech requires a much shorter reverberation time than that ideal for live music[2] (Egan 1988).

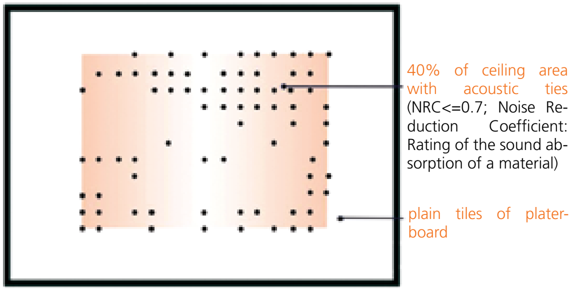


Figure 10: In new or existing classrooms with floor areas of 100 m^2 or less, covering 40% of the ceiling area with acoustic tiles is a low-cost and efficient option for noise reduction.

Figure 11: Multi-purpose hall (Reverberation Time is flexible from 0.8 to 1.2 seconds

2. Sounds bounce off hard surfaces, such as painted walls and vinyl floors, so that listeners hear several indistinct, overlapping versions, which smear the original sound. The sound continues for a time, reflecting around after it has stopped at its source. This is called 'reverberation'. The length of time the echoes take to die away is called the 'reverberation time'.

Consequently, multiple sound requirements have to be addressed in a multi-purpose hall (assembly hall). Surfaces for sound absorption and reflection may be needed and adjusted to fit specific purposes. Normally, the effect of adding sound-absorbing treatment to a room is very significant. Porous material is a good acoustic absorber, for example, heavy curtains, soft chairs. Here is an example of a multi-purpose hall (Figure 11). The room is used, without changes as a sports hall, assembly hall, theatre and concert hall. Thanks to early planning and measurements taken in the shell, an aesthetically attractive solution with good linearization of the reverberation was achieved by optimising the ceiling (slightly convex, vaulted gable areas) and installing acoustic panels, curtains and screens on the walls and door.

3.1.3 Temperature

Basically, thermal comfort in a building is achieved by maintaining temperature, humidity, air movement and human activity conditions within a certain range. Space heating and/or cooling loads, which are required to maintain this comfort, to some extent, depend on the building's quality itself to modify the external conditions and how far the outdoor conditions are from the acceptable range. (Szokolay 2003, p63)

There are three building design options practically which have the greatest influence on thermal performance:

- ➔ Orientation: solar heat is the main source to warm the surface of the whole Earth and every single building anywhere in the world. The Earth's movement in relation to the Sun can be calculated with great accuracy, and so the orientation of the building will have a predictable impact on the indoor environment.

- ➔ Building layout: links to the building shape, which heavily affects the heat gains and losses, as the exchange between the outside and the envelope is directly proportional to the surface area.

- ➔ Windows: the larger the windows the more the solar gain and the greater the heat loss.

Orientation

Fundamentally the room orientation determines what time and how long the amount of solar heat is received (Figure 12). This is to be expected as the rooms towards the South receive the most solar radiation of all the different room orientations. The rooms can heat up quickly, especially when the sunlight penetrates directly into the room. The rooms towards the West experience stronger and more intense sunlight and sun heat than those towards the East. The North rooms, on the other hand, do not receive direct solar radiation for most of the time. (In the UK, due to its high latitude position, around 23rd of June, the North rooms in some areas may experience the direct sunlight in the late afternoon.)

In order to take advantage of the solar heat as much as possible, in most instances the North and South walls should be longer than the east and west ones. A rule of thumb is that a ratio of around 1.3 to 2.0 will optimize wanted or unwanted heat gain or heat dissipation in terms of solar incidence (Littler and Thomas 1984; Szokolay 2003 p64).

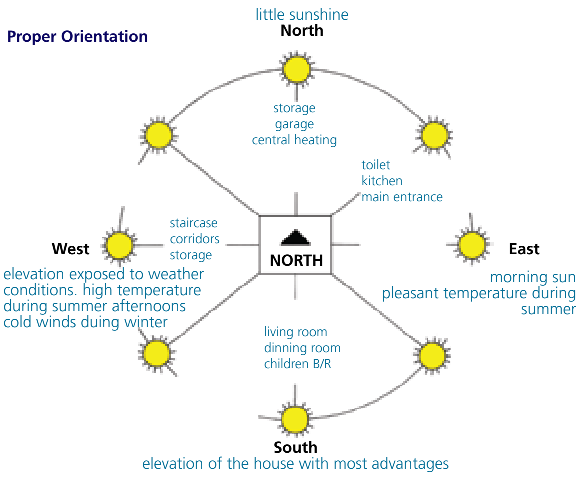


Figure 12: Proper orientation of a building (north hemisphere)

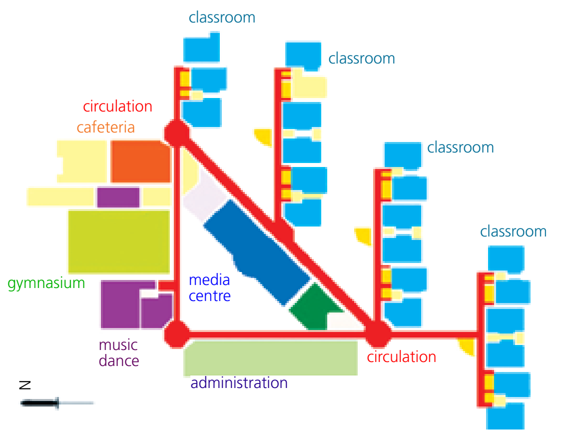


Figure 13: Building plan (Davidson Elementary School, Charlotte, N. Carolina, US - Confirmatory Case)

Davidson Elementary School is in North Carolina, US. The design takes advantage of Southern sun exposures to enhance indoor and outdoor learning activities. In this case, all classrooms are set out with large windows orientated to the South (Figure 13). Each classroom also has an outdoor learning area for creating art and science projects as well as supporting classroom activities. The day lighting concept developed for the project includes providing a light shelf. The purpose of the light shelf is to reflect sky light throughout the classroom area as shown in Figure 14. The translucent porch canopy also allows natural light to enter the classroom while providing necessary.

Figure 14: South facade with translucent porch (Davidson Elementary School, Charlotte, N. Carolina, US - Confirmatory Case)

Layout

The layout normally is strongly linked to the building shape: its room arrangement, size, height and pattern. And the shape further determines the building's surface to volume rate, which is defined as the ratio of the area of external walls with respect to the volume of the building. Heat exchange between the outside and the envelope is directly proportional to the surface area. Therefore, any changes to the layout that increase the surface area exposed to the air outside will result in an increased heat exchange rate (Ogoli 2003).

Figure 15 shows that the more complex the form, the greater surface area to volume it will have. This may result in more heat loss with more exposed surface, but less heat gain due to self-shadowing. Thus, it is advisable to present the lowest possible surface area for a given volume because it can offer advantages for the control of both heat losses and heat gains through the building skin without conflict between design priorities for winter and summer conditions (Lewis 1992, p97). This suggests a compact and simple plan is better in this context than a spread-out and complicated arrangement. Other strategies may accompany this such as additional insulation and attached buffer spaces to offset the heat loss due to increased surface area.

Windows

The arrangement of the windows and other openings in the walls provides the main architectural character of a building. It is a critical control element in regulating the whole environment of a room by providing an opening for the flows – inward and outward – of heat, light, sound, air and view. A window performs an important role in the thermal environment of the building. The larger the window the more the solar gain and the greater the heat loss (Ward 2004, p16).

Figure 16 shows some typical glazing options' U-values (Nicholls 2002, p55)[3] . Normally glazing has a very high U-value, except in those cases where a special insulation treatment (low E coating) has been applied, which means windows can be a weak thermal link due to their high heat transference, in and out. In Summer, this can be problematic not just from the overheating resulting from heat gain, but also owing to the rise in radiant temperature from the glass surface. In Winter, the heat loss from windows becomes a problem and in addition, the cool surface temperatures can also lead to great discomfort (McEvoy, M. 1994, p40]. To effectively address the

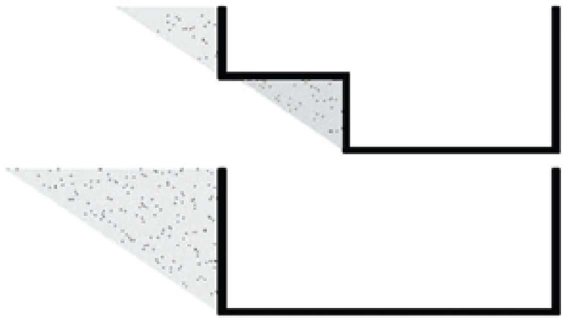


Figure 15: Effect of plan on self-shadowing

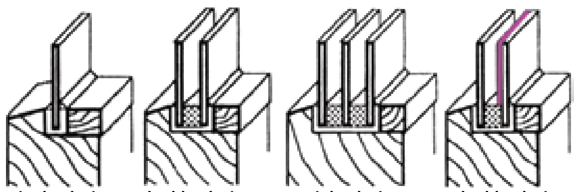


Figure 16: U-value against cavity width for glazing (unit: W/m²K)

3. U-value is a measure of thermal resistance, used in the building and construction industry. Under uniform conditions it is the ratio of the temperature difference across an insulator and the heat flux (heat flow per unit area) through it. The bigger the number, the lower the material's insulating effectiveness.

heat balance (loss and gain), it is important to minimize the size and maximize the transmission of sunlight of apertures. Of course this can conflict with a desire to maximise daylight. Thus, Table 2 suggests criteria and appropriate glazing choices for each particular application in schools (Innovative Design 2004, p10).

Table 2: Suggested glazing choices

Application	Exposure	Type
Glass for daylighting	Any orientation	Clear double
View glass (non-daylighting apertures)	South	Clear double, low-e
	North	Clear double; low-e
	East/West, unshaded	Tinted double, low-e
	East/West, shaded	Clear double, low-e
High windows above view glass	South	Clear double, glass or acrylic
Clerestory windows	North	Clear double, glass or acrylic
Roof monitor	South	Clear double, glass or acrylic

3.1.4 Air quality

Air quality has become increasingly important nowadays due to several factors: constant internal conditions, limited fresh air, absence of daylight and universal use of carpets. They provide an ideal environment for house mites to damage the air quality of a room (Burberry 1997, p48). This contaminant has been identified as a cause of discomfort and health problems.

CO_2 is not considered a contaminant or pollutant at the levels normally measured in buildings, however, it is widely recognized as an indicator of ventilation rates inside buildings in that certain levels of CO_2 indoors correspond to various ventilation rates. A comprehensive study was performed by Coley and Greeves (2004), which investigated the effect of low ventilation rates on the cognitive functions of a primary school class. The study used a battery of standardised, computerised tests and demonstrated that the attentional processes of school children are significantly slower when the level of CO_2 in classrooms is high. Increased levels of CO_2 led to a decrement in 'Power of Attention' of approximately 5%. The report quantifies this effect as of a similar magnitude to that observed over the course of a morning when students skip breakfast.

Shendell et al. (2004) examined the association of student absence with carbon dioxide concentration. The report found that 45% of classrooms had short-term indoor CO_2 concentrations above the local ASHRAE 1000 ppm recommended limit and stated that a 1000 ppm increase in the difference between indoor and outdoor CO_2 concentration was associated with a 10–20% increase in student absence and that the association was statistically significant. The report concluded that, if future studies concur, improving classroom ventilation should be considered a practical means of reducing student absence. Although a statistically significant association between CO_2 levels and absence was found, it is worth noting that this may be an indicator rather than a cause, as low ventilation rates will increase communicable respiratory illnesses (Fisk 2000).

Clearly, indoor air quality and adequate building ventilation are closely linked and inadequate is a common problem in schools. Children are particularly vulnerable to all types of pollutants because their breathing and metabolic rates are high. In a school they also have much less floor space, by a factor of 10, allocated per person, than adults working in a typical office (Crawford 1998).

Two practical options are addressed here:

- ➔ Orientation: this is mainly in regard to the prevailing wind. It can be either desirable or unwanted. With careful design, as much wind as possible can either be received or diverted.

- ➔ Window: as mentioned before, it is a breach in the enclosing skin of the building, providing an opening for the flows – inward and outward – of heat, light sound, view and air (ventilation).

Orientation

In order to protect occupants from adverse polluted air exposure, both from outside and inside the building, much work and research has been done on the built environment relating to air quality control. Initially, the exterior is usually checked in order to evaluate the general situation. If the school is unavoidably near some polluted source, such as the carbon monoxide gas from a motor vehicle exhaust or sulphur dioxide released from factories, it is important for a school to be located as far as possible from the source and also on the windward side in terms of the local prevailing wind direction (Meyer 1983).

Similarly, spaces or rooms creating strong smells need to

be located and separated from the main learning areas. This is particularly true when it comes to the cafeteria and the kitchen within the building. As well as being placed on the leeward side of the rest of the school (Figure 17), special measures can be taken in order to filter and extract the smelly air the spaces produce, using for example mechanical ventilation systems. Only in this way with careful design and planning can eliminate, or at least reduce, the impact of polluted air on the school environment.

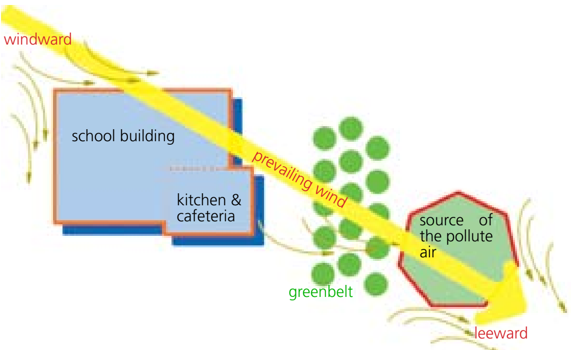


Figure 17: Based on the local predominant wind direction, the school should be located away from the pollute air.

Windows

Wind pressures are positive (push) on the windward side of the building and negative (suck) on the leeward side. This encourages good cross-ventilation in rooms with windows and/or doors on opposite sides. This also has to be carefully controlled to prevent too much air movement in windy conditions. For much of the time, windows are used to provide passive ventilation. Therefore windows have to be carefully designed to allow for different weather conditions. Ideally, windows in classrooms should have ventilation options that include all of the following (Figure 18, 19):

- small, high-level windows, which allow small amounts of ventilation in high wind;

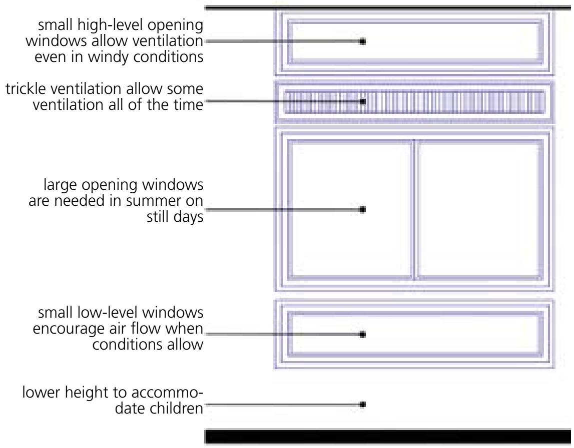


Figure 18: Ventilation options for varying conditions

Figure 19: Small windows at the top, allowing ventilation without draught (Rolls Crescent Primary School, Manchester, UK - Confirmatory Case)

- trickle ventilators for cold weather, high winds and when other windows are closed for security;
- large, main central windows for still, hot, summer weather;
- small windows at bench height for all-round ventilation – may have to be closed in high winds to prevent papers flying.

3.2 Individualisation

As an individual matures their brain builds a very personal set of connections between primary reinforcers (basic needs) and complex representations of secondary reinforcers (features in the world). Taken together with the situated nature of memory, these personal value profiles lead to highly individual responses to space. This provides a sound basis to raise the potential importance of 'individualisation' as an additional, key, underlying design principle. This appears to play out in two ways: particularisation and personalisation. Particularisation concerns accommodating the functional needs of very specific types of users, for example learning and wayfinding in the context of age and physical requirements. Personalisation concerns an individual's preferences owing to their personal life experiences of spaces. These of course will vary greatly from person to person, but the desire is evident in the way people seek to individualise spaces.

Of course particularisation and personalisation are not discrete aspects. For example, personalisation using possessions and precious things helps us reinforce our own sense of indentify as part of a developmental learning process. These same artefacts are also an important way for people suffering with Alzheimer's disease (a particular user group), to shore up personal memories that are becoming fragile and to cope with their environment (Zeisel 2006, p357).

The challenge facing schools is to balance the need for individualisation, with creating inspiring buildings with functional spaces that are appropriate for new educational developments and new technologies, but adaptable enough to cater for the pupils' changing needs in the future. It is not possible to create a plan that will work forever; however, three key issues would seem to link school design with considerations of individualisation, and these provide a framework within which change can take place:

- ➔ Choice: is concerned with the 'fit' between individual personality and the physical environment, which consists of the mental process of judging the size, shape, height of alternative spaces and how appropriate they are for the task.

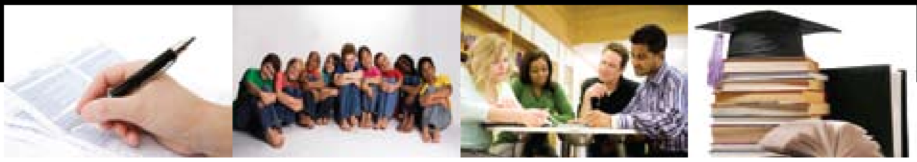
- ➔ Flexibility: refers to designs that can adapt when changes occur, sustaining or increasing the possibilities for personalising space and delivering value in a timely and cost-effective manner.

- ➔ Connection: joining and being joined, it mainly refers to the relationship between spaces within the building, but also between the school and the neighbourhood within the community. In either case issues arise of distinctive personality, easily identifiable destinations and the opportunity for inclusion.

Designing places with respect for scale and developmental need means all learning environments should be: learner-centred, developmentally- and age-appropriate, comfortable, accessible and equitable. There is evidence that 'varied' classrooms are related to higher levels of voluntary participation and that overall aesthetic quality in education facilities is related to students' task persistence (McMillan 1997). Interestingly, Zeisel et al. (2003) have studied the impacts of holistically designed care environments on the well-being of Alzheimer's patients and found that providing them with both privacy and the opportunity to be surrounded by familiar furniture, décor and treasured objects aids them in maintaining a sense of self and improves their recollection and memory. Although this finding was not conducted with children it raises the issue that small, intimate and personalised spaces seem to be better for absorbing, memorizing and recalling information.

The brain function highlights the personal way in which individuals build connections between primary reinforcers and complex representations of secondary reinforcers.

In order to easily accommodate diverse instructional modes, there is no doubt that maximizing flexibility is essential for contemporary and future-oriented schools. For example, designing for a variety of learning groups and spaces can be directly linked to improvements in achievement. Research (Achilles 1992, Finn & Achilles1990) shows that children in smaller classes were found to outperform children from regular class sizes in all subjects, especially in reading and mathematics test scores with average improvements of up to 15%. Followed-up tests that used the same schools have shown that students previously in small groups demonstrated statistically significant advantages two years later over students previously in large groups. Performance gains ranged from 11-34%.



Safe, clear and varied connections experienced by people may help increase their sense of direction, stimulate imagination and influence their educational performance. School buildings and grounds with 'clearly defined areas for freedom and movement' have been found to correlated significantly with higher ITBS (Lowa Test for Basic Skills) scores (Tanner 2000).Today, school activities involve more than simply listening or writing. Learning can take place in many different kinds and qualities of space. In addition, students activities outdoors (e.g. playgrounds) have shown to be more creative than in classrooms or traditional playgrounds (Lindholm 1995), with positive effects on learning and cognitive qualities (Fjortoft and Sageie 1999; Fjortoft 2004).

3.2.1 Choice

People come in all different shapes and sizes, and with different capabilities and limitations in strength, speed, judgement, and skills. All of these factors need to be considered in the design function. To design a physical built environment, physiology and psychology research indicates that personalization of space is an important factor in the formation of an individual's identity and sense of self-worth. Pupils in schools are a lot like workers in the workplace in that it is important for most people to have some space / facility that is their own. By providing similar forms of personal space (facility) within the school for each individual, those pupils will gain more positive sense of self and take pride and ownership in their school. Here are two successful and easy ways:

- ➔ Rooms: within the physical boundaries of each instructional area, spatial variety can be achieved by different room heights to create an intimate atmosphere.
- ➔ Windows: similarly, they can be smaller and heights lower to accommodate children, especially where they reflect ergonomic considerations.

Rooms

The size and scale of the building, its exterior elements and its interior spaces, make it possible for pupils to use spaces independently in a manner consistent with their evolving developmental capacities. For child centred spaces, elements and spaces can be smaller and heights lower to accommodate children in order to create more intimate, interesting and engaging spaces. Of course, in this case, comfort for both children and teachers will require some compromises between child, youth and adult-scales.

The design of Kindergarten Jerusalemer Straße encourages exploration and extends spatial understanding. The external treatment supports this legibility by means of coloured render with horizontal banded windows stepping back from the flat-faced facades (Figure 20). A further element of this composition is the projecting bay windows. They bring a sense of spatial variety, as each balcony/bay is ranged across the three-storey street facades. From the outside they express the sense that this is a building for children as well as for their adult carers. However, the bay windows are also highly functional. Each activity area has one of these bays scaled to the height of a child; smaller groups of children can withdraw from the main activity areas and into their safe elevated little playhouses high above the street.

Figure 20: (Top) View from the street; (Bottom) Bay window detail from the inside (Kindergarten Jerusalemer Straße, Berlin, Germany - Illustrative Case)

Another successful case is the campus-based childcare facility in the University of California at Los Angeles (US). It incorporates a large classroom which is divided into dedicated activity zones (for wet play, art, reading and manipulative play). The internal areas have lots of spatial variety, with different height floors in tune with both the scale of small children and their diverse patterns of play. For example, the main play area has a high ceiling and large size; whereas the dedicated quiet room is small, low and intimate. Child-height and adult sinks are separated for diapering, for food preparation, and art and general activities (Figure 21, 22).

Figure 21: Interior view of the main playroom with clear-defined activity area (Corner one, Childcare facility in the University of California, Los Angeles, UK - Illustrative Case) (Source: www.spacesforchildren.com)

Windows

Ergonomics is about more than a comfortable, adjustable chair and desk. Ergonomics considers the entire environment and how it supports and interacts with the child's body. Well-planned pathways, open access to equipment and supplies, ease of moving furniture and creating interesting and engaging spaces are all ergonomic considerations. Window design can also relate to ergonomics and make it possible for children to use spaces independently in a manner consistent with their evolving developmental capacities. For child-centred spaces, windows can be smaller and heights lower to accommodate children. It not only minimizes the institutional character of buildings but also creates more intimate spaces.

For example, from the activity areas in Pen Green Early Excellence Centre (Corby, Northamptonshire, UK), children can enjoy the sunlight and have a clear view of the landscape through a continuous glass wall, which wraps around the classroom. The glazing height is only available to children with soft benching. Adults are denied the views the children have, unless they get down to child level. It is a privilege that the children recognise is theirs within this child-oriented environment (Figure 23).

The National Day Nurseries Association is a charitable organisation. The design of NDNA East Midlands Regional Centre develops the constraints of the room schedule by

Figure 22: Interior view of the main playroom with the lower and higher floor planes giving spatial drama to the activity area (Corner two, Childcare facility in the University of California, Los Angeles, UK - Illustrative Case) (source: www.spacesforchildren.com)

Figure 23: Low-level child height window is balanced by its high level twins (Pen Green Early Excellence Centre, Corby, Northamptonshire, UK - Confirmatory Case)

adopting a metaphor of growth. The idea is that as children grow, so the building should grow; this was taken as a key design idea, with the gentle tapering of the building's form in plan and in section (Figure 24, left). As its lowest and narrowest point, there is the baby room, an intimate enclosed zone appropriate for the youngest and most vulnerable, the children's activity rooms are ranged in ascending age order around the courtyard, so that the final room for the oldest preschool children is a lofty spacious area, symbolically encouraging children to be more active and adventurous (Figure 24, right).

3.2.2 Flexibility

To determine an appropriate school design, classrooms usually play the most important role as they are the core space of a school. Therefore, it is required to provide opportunities for the greatest flexibility to anticipate changes in pedagogical goals and educational programmes, reflected in organizational strategies (e.g. grade-level groupings to multi-age groupings of learners) or instructional strategies (e.g. team teaching and interdisciplinary instruction).

One practical option stands out:

➔ Rooms: Classrooms make up the main body of school buildings. To maximize the flexibility of instructional clusters, there are several considerations:

- Open plan and cellular classroom: no matter in which form, it is important to identify the proposed activities that are likely to take place and provide a well-defined area that offers resources that can be shared by students.

- Classroom size: involves the determination of the average number of children involved with each activity and calculate the amount of space each child will need to function as they participate in that activity.

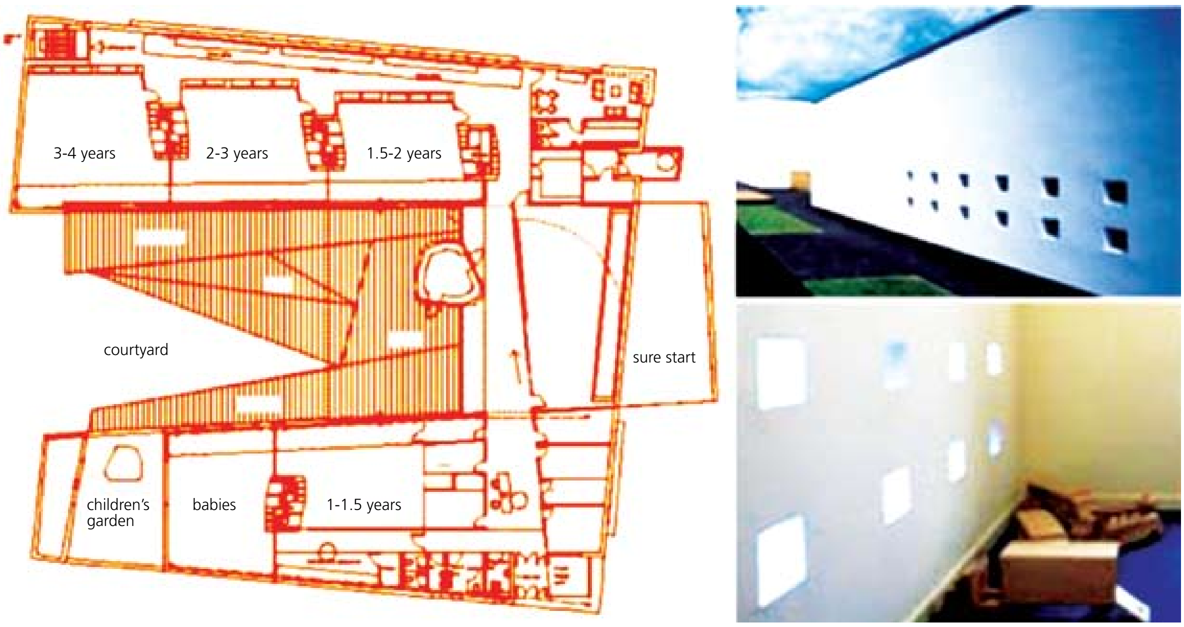
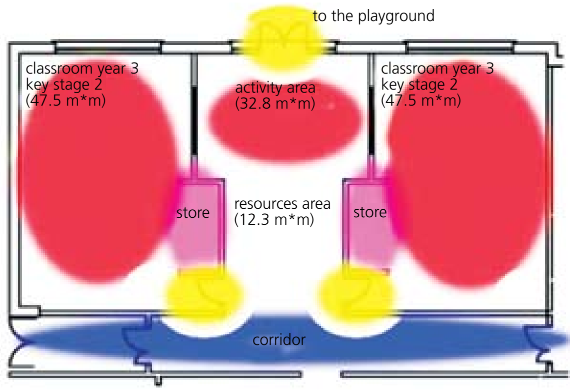


Figure 24: (Left) The building is a metaphor of growth. As children grow, the building grows in plan and section; (Right) End façade with child height coloured optic windows (NDNA East Midlands Regional Centre (National Day Nurseries Association) Spitalgate School, Grantham, UK - Illustrative Case)

- Classroom layout: the amount of space a child will need varies with the activity, such as reading, writing, working or simply listening. Therefore, the plan has to be able to accommodate instruction, experimentation, or group related activities.



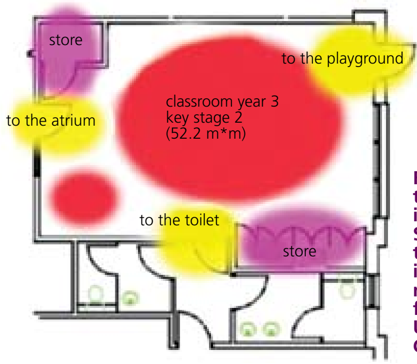


Figure 25: (Top) A typical classroom in Temple Primary School; (Left) A typical classroom in Green End Primary School (both from Manchester, UK - Confirmatory Cases)

Rooms

Open plan and cellular classrooms

Modern school buildings cover a broad spectrum of layouts. The majority have traditional closed cellular structures, with the basic teaching space a classroom, being used for lessons for groups of between 14 and 30 pupils. Open-plan classrooms, on the other hand, are intended to provide more opportunity for pupils to explore the learning environment. Apart from its pedagogical intent, one of the most important aims of open plan is flexibility and adaptability so that schools can respond to changes in delivering teaching and learning. For example, the open-plan classroom allows for as wide a variety of group learning sizes as possible and have learner groupings from an entire "family" of 30 or 40 learners, to groups of 12, 4-6 and 1-2 learners. At the same time, each large-group, small-group, and/or individual learning space should be an architecturally well-defined "activity pocket" with all the furniture, equipment, storage, and resources necessary for that learning activity contained within.

A comparative study (Figure 25), which was carried out in Manchester, has shown that the essential element of 'open plan' is not just about big classrooms, but concerns the educational philosophy and the details of the physical layout. Although the classrooms in Temple, (Manchester, UK) are not particularly sophisticated, it is what is immediately outside the "traditional" classroom which is significant. The shared activity area here makes the teaching situation flexible as the shared space is an extension of the classroom. The teachers can have break-out groups anytime as this third area is always available.

In contrast, the flexibility of use of the large classroom at Green End (Manchester, UK) is relatively poor. This is not because of the size, but mainly because of its layout - the doors, windows and storage areas greatly reduce the space actually available for teaching activates. This makes it impossible to teach using new learning styles as teaching can only take place in a formalised layout of rows of pupils. Teachers have to stay in one place, essentially 'taught from the front' and cannot move the furniture. Sometimes, the teachers in this school mention that the children cannot see clearly when they try to teach in the classroom using the board. Thus the 'open-plan' classroom in Green End is less flexible in practice than the traditional cellular classrooms in Temple, where they are appropriately linked to related spaces.

Classroom size

It is not uncommon to have up to 30 children in each class (Figure 26). In a crowded classroom, pupils can easily be overlooked due to the size of the class. High density situations (too many children or too little space) can lead to excess levels of stimulation, stress and arousal, reductions in desired privacy levels and loss of control (Wohlwill J and Van Vliet W 1985).

Figure 26: Overcrowded classroom

Blatchford et al. (2003) summarises results from the most complete UK analysis to date of the educational consequences of class size differences. The study followed a large sample of over 10,000 children in UK and results showed that there was a clear effect of class size differences on children's academic attainment over the (first) Reception year. For example, Figure 27 shows the Reception year's progress in literacy varied for pupils of differing baseline attainment. Pupils were split into three ability groups, based on their pre-Reception year literacy scores (bottom 25%, middle 50% and top 25%). There was a strong and significant increase in attainment for all three groups, though there was a larger effect for pupils with lower baseline attainment. A reduction in class size from 30 to 20 pupils resulted in an increase in attainment of approximately 0.35 standard deviations for the low attainers, 0.2 standard deviations for the middle attainers, and 0.15 standard deviations for the high attainers.

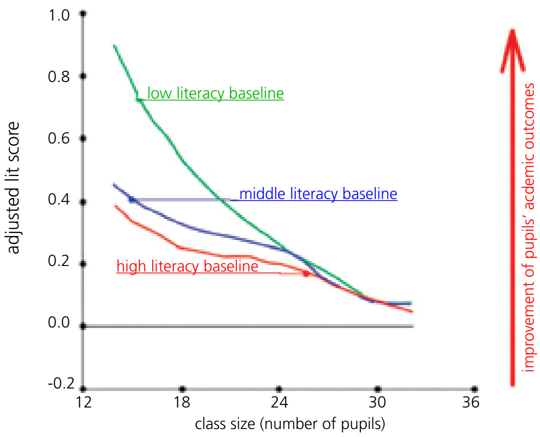


Figure 27: Relationship between 'Reception' year class size and literacy progress (adjusted for school entry scores)

The design of Redbrook Hayes Community Primary School in Rugeley, Staffordshire, UK pays much attention to bringing as many as learning spaces as possible into the heart of the school so that children and staff are in constant contact with daily school activities (Figure 28). Full ranges of closed classrooms are toward the east to west. Each partially glazed permitting a sense of spatial transparency. This transparency is further enhanced by generous floor to ceiling zones, with natural daylight pouring in from high-level clerestory windows running both sides of its entire length. Each classroom has its own children's toilets, kitchen area, generous range of storage and integrated ICT. Doors lead out to run-in run-out play areas from each classroom. Moreover, in the

Figure 28: Large classroom with varied learning groups and spaces (Redbrook Hayes Community Primary School , Rugeley, Staffordshire, UK - Confirmatory Case) (Source: CABE/A&M Photography)

heart of the school, there are many different hub areas for small group work in order to increase the flexibility of each classroom (Figure 29).

Based on informal feedback from staff and pupils, the majority of comments have been overwhelmingly positive. Now that children are settled and secure, they are more engaged and interested in their education. A member of staff commented on how much happier staff and children were since they moved into the new building: 'It has certainly improved SATS results and attendance levels are much better, they seem to enjoy beving here; it is a wonderful place to be.' Certainly this significant improvement will have resulted from many factors; but it is also a direct effect of this superb new building, according to the headteacher.

Classroom layout

There is no perfect classroom design. However, Lippman (2002, 2003) in his study of schools mentions that providing a variety of spaces within a classroom supports student-teacher / child-adult relationships. With the understanding that schools are learning centres for development, and building on his research findings, Franklin (2008) recognized that non-traditional, modern learning environments could encourage students to fully participate in activities with others as they acquire knowledge for themselves. He then developed the following criteria for the modern classroom:

- It has to accommodate the formation and functioning of small learning groups while providing a sense of separation, because groups working together will experience distractions and non-productive interaction.
- It has to be flexible enough to allow the continual reorganization of the whole class into various sizes and number of small learning groups. This means the space must be as free as possible of permanent obstructions.
- It has to be manageable by a single teacher who has command of the entire space. This means the space must be compact and open (Dyck 1994).

Based on this, Dyck (1994) proposed the layout of the 'Fat L' as a design pattern that offers teachers options in how they might organize their classrooms to facilitate the development of their students in various learning activities. Since this article was written, much work has been done on how the 'L' Shape design pattern might influence learning as well as be incorporated into the design of new school facilities. Figure 30 shows a simplified version of how such a classroom might be arranged (Franklin 2008). Three distinct macro-level zones are

Figure 29: Different hub areas in the central space for small group work (Redbrook Hayes Community Primary School , Rugeley, Staffordshire, UK - Confirmatory Case) (Source: CABE/A&M Photography)

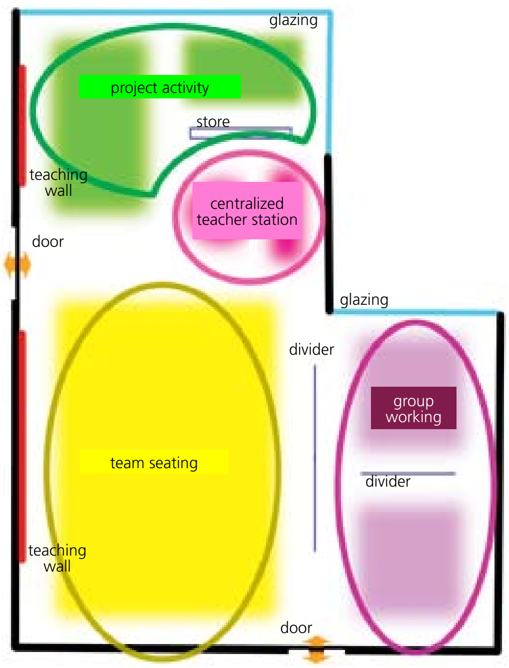


Figure 30: Conceptual 'L' shaped classroom

available for very different educational activities including large group and individual desks, art or team-based group activities with electronics.

The Prairie Hill Learning Centre (Figure 31) is an elementary school in which the 'Fat L' classrooms are paired. The design reflects an understanding that learning is not defined to an area, but rather occurs between settings. In addition, the structural column located approximately in the centre of each classroom assists in defining areas in which different activity settings may be organized. Yet, they don't disrupt the flow of activity within the classroom. The Prairie Hill Learning Centre within its simplicity is a rather complex design. Not only do the physical elements afford flexibility and variability in the creation of the activity settings, they also afford an integrated learning environment within the classroom as well as between the classrooms where pupils may always be engaged in the activities of others as they work on their

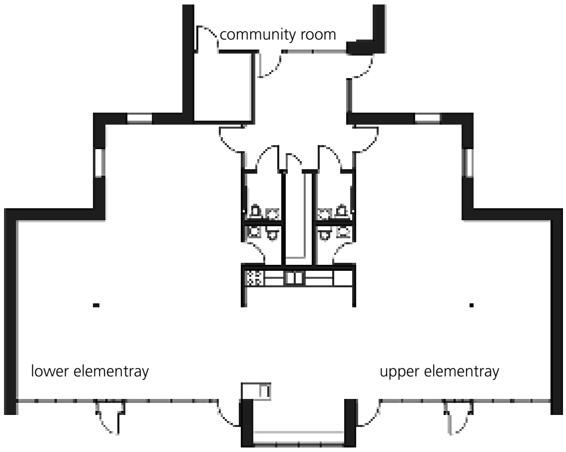


Figure 31: (Top) Building Plan; (Bottom) View from the outside (The Prairie Hill Learning Centre, Roca, US - Illustrative Case) (Source: The Architectural Partnership Photography)

tasks-at-hand. This layout is, of course, very like Temple Primary (see Figure 25) in principle, although Temple is, on the face of it, a traditional layout. The important thing is really the functionality of the spaces in practice, not whether they are new or old.

3.2.3 Connection

In terms of school design, connection, on one hand, involves pathways between spaces within the school building. In this case, safe, easy movement and allowing surveillance are three basic requirements. On the other hand, connections also refer to the allowance of school and community functions to be integrated into a cohesive network of closely adjacent facilities, creating an involvement and awareness of the educational process. Therefore, these two aspects are emphasized in this report:

- ➔ Circulation: within schools, clearly marked pathways to activity areas improve the utilization of spaces. And they help keep the children orientated and stimulate their imaginations (Alexander 1977). Creating activity nodes between pathways can also increase opportunities for extra learning and positive social interaction.

- ➔ Location: outside the school, its location can create reciprocal opportunities with the local community's existing neighbourhood resources in order to foster meaningful inter-organizational partnerships that can strengthen educational opportunities and enrich school life for students.

Circulation

Circulation such as hallways and corridors are a costly percentage of a school building. The circulation provision has to create gentle transitions from different spaces, taking advantage of turns and bends to create unique areas of learning. Conversely, for issues of safety, circulation paths also need to ensure supervision by, not only administrators, but also students, teachers and parents. Poorly designed circulation can make movement around the building difficult and even facilitate bullying. It is not just a corridor. It is a critical dimension where good design can make a real difference to spatial quality.

The Kingsmead Primary School has seven classes with 212 pupils. The building plan and overall form is deceptively simple. The floor plan for this school is based on a curved shape. A central spine houses all the large and specialist spaces which are most likely to be used with pupils and teaching staff (Figure 32). The corridor has been made an asset by providing rooflighting and display areas along it. Bright colours, such as blue, green red etc. have been used to create identity for young children or those with visual impairment, helping them to orientate (Figure 33). The gentle curve of the corridor, resulting from the crescent plan, prevents it looking in any way institutional.

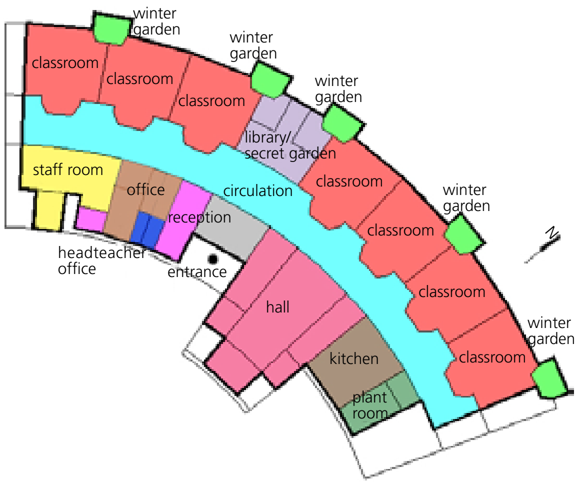


Figure 32: The school follows a curved plan with a central corridor, clear and simple (Kingsmead Primary School, Norwich, UK - Illustrative Case)

Figure 33: Colourful circulation with children's art displayed on the walls (Kingsmead Primary School, Norwich, UK - Illustrative Case)

Creating central activity nodes, or break-out spaces, which connect short paths, is one strategy for maintaining visual supervision without creating long institutional-style corridors and increasing opportunities for positive social interaction. Small group instruction can be provided in break-out spaces. The ability to instruct a few children or individuals on similar topics, at different paces and in different ways, allows for the customisation of each student's personal profile.

When break-out spaces are developing into scalable environments, they can nurture both individual students and small-group work with an emphasis on collaborative work and the recognition of the need to accommodate multiple learning styles. Interior windows and openings can further allow for effective break-out spaces in the nooks and crannies off circulation routes that were previously perceived as unusable spaces.

These spaces have become secondary instructional areas by allowing an instructor to maintain supervision over more than one area at a time. It has to be noted that these breakout-out spaces need to be carefully designed to avoid causing problems like congestion, aggression and destructive behaviour. Normally, the corridors for movement should make efficient use of the available floor area, but where appropriate they can articulate with break-out spaces where social and / or study can take place (Figure 34).

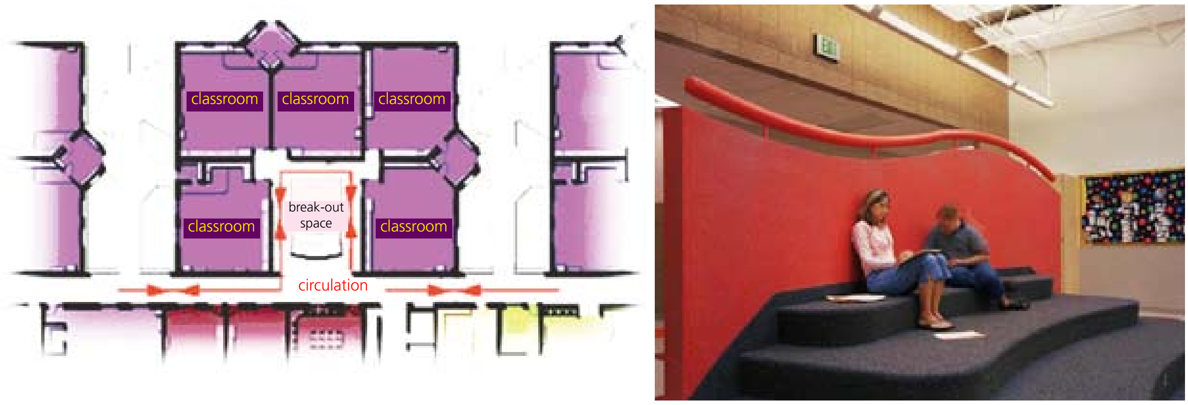


Figure 34: (Top) Part of the school plan; (Bottom) One of the break-out space at classroom clusters (West Haven Elementary School, West Haven, Utah, US - Confirmatory Case

Figure 35: (Left) Visit from Hampshire Fire Brigade; (Right) organic vegetable garden (Farnborough Grange Nursery and Infant Community School, Hants, UK– Confirmatory Case)

Location

When it comes to planning schools as community learning centres, much has been emphasized in terms of making school resources available to the wider community, for example, by co-locating additional services like early year's facilities, health and adult training (Building Bulletin 95, 2002). However, there is another important aspect of the relationship between local community and schools. Learning things in the classroom and then seeing them in real life outside the school is often a much more powerful, practical way of remembering and understanding than simply learning from a lesson alone. Some of the external experiences children could take to engender learning in action may include:

- Botanical garden: real biology lessons;
- An old building and/or ruin: part of history lessons;
- All kinds of theme museums and galleries: science and art in action;
- Theatre: English lessons on plays.

Besides, children can learn new things without even realizing it. For example, they will know love, care and respect if they visit a Community Centre to play board games with each other and elderly people, or even just to sing a song. Though the link with community may appear to be a social feature or educational decision, designs can affect it. When planning a school, its location might take advantage of the local community's existing neighbourhood resources. In this way, the 'natural societal settings' and 'formal instructional settings' can be regarded as complementary to each other, the advantages of which are maximised at all times in order to provide sufficient, interesting and welcoming learning opportunities.

There are many examples of good community schools. Farnborough Grange Nursery and Infant Community School in Hants, UK involves a wide range of community links from the local area for 'practical and meaningful' education (Figure 35).

For example, a school visit from the Hampshire Fire Brigade gave pupils opportunities to learn about safety and security. Pupils in this school also grow organic vegetables at school (science, environmental and health education) and harvest them for sale to the local community. Profits go to help local homeless people (charity work / understanding the needs of others), but some food is kept by pupils to cook meals for the elderly (or "elders" as they are known) in a local centre. They perform songs for them, and visit the centre at regular intervals. The elders, in turn, visit the school to help with the garden, talk with pupils, and help with projects.

Rolls Crescent Primary School in Manchester, UK is another successful example (Figure 36). The school is located in a well-defined neighbourhood, the sense of cohesion experienced by community members helps increase people's involvement in neighbourhood schools. In 2007, this school had a very impressive grounds week, in which they used the grounds extensively for a week, having lessons and other activities outside. The school also used its strong neighbourhood links in order to directly influence its educational performance, such as periodic visits to the Hulme Commnity Garden Centre, Elderly Resources Centre. From these experiences, children increased their self-esteem and learnt about health, science, local past, participation and social skills education. There are shared school and community facilities that make up a cohesive network of closely adjacent opportunities. This network has created an environment that interlaces a residential area, the wider community and the school together and increases interaction between them.

Figure 36: Pupils can reach these communities and facilities without passing streets (Rolls Crescent Primary School, Manchester, UK - Confirmatory Case)

3.3 Level of Stimulation

Lying behind the detail of design elements for general and particular needs there is also a recurrent theme around the general level of stimulation that is appropriate for given situations. In broad terms this may vary from buildings designed for relaxation, such as, homes, to those designed to stimulate, such as theatres, but also variation will be appropriate within buildings. So in a school, classrooms may need a different approach from assembly areas. Thus, a link can be seen here with the issue of individualisation, stressing the holistic nature of design solutions. In the context of judging design competitions, Nasar (1999, p77-85) reinforces the central importance of the level of stimulation produced. Drawing from an extensive literature review he suggests that combinations of pleasantness (or unpleasantness) and different levels of arousal yield either excitement (or boredom) or relaxation (or distress)

Combinations of pleasantness and different levels of arousal yield either excitement or relaxation. When the level of stimulation is appropriate for given situations, certain reactions take place positively in the brain and mind, affecting mood, mental clarity and energy levels.

In spite of individual differences, people have shared meanings and these can serve as a basis for building design. When people look at a building or a space inside, they may judge how much they like it or how pleasant it looks. If one judges a place as exciting or boring, the judgement refers to its level of excitement. If one judges a place as relaxing or distressing, the judgements refer to its level of relaxation. Exciting places are more pleasant and arousing than boring ones. Relaxing places are more pleasant but less arousing than distressing one. (Russell and Ward 1981, Russell and Snodgrass 1989).

Research confirms many aspects of human emotional response to buildings and places (Nasar 1988, Hanyu 1993, Mahnke 1996). For a school design, three parameters stand out in occupants' sensation, perception and evaluation of the physical environment:

- ➔ Complexity: refers to visual richness, which can be related to the number of noticeably different elements in a scene (diversity) without negative content such as clutter and disorder. This often needs to be balanced with a degree of order (unity) in order to provide clarity and familiarity.

- ➔ Colour: has been proved to have a great impact on human's psychological reaction and physiological well-beings. The perception of colour in the environment always carries visual, associative and symbolic effects with it.

- ➔ Texture: refers to the perceived prominence of materials' characteristic. Along with colour, it is considered as one of the primary abstract elements of design. By combining hard and soft surfaces, texture can animate indoor and landscape experience by complementing built aspects with natural elements.

In spite the fact that buildings are complex visual objects in children's environment, they represent one of the most frequent subjects of children's drawings, second only to humans and animals. Buildings are not as stereotyped as, for example, their drawings of human beings, therefore, the study of children's drawings of buildings often amounts to an investigation of their iconic coding of the environment (Krampen 1991). Kerr (1937) obtained house drawings from 555 children covering the ages of 6 to 14 years. She found that the tendency toward elaboration is influenced by general intellectual development and emotional development of fixation. Children's preferences were reflected by the complexity of their buildings: the forms and structures, rounds and arches, window and door fittings, two-sided houses and perspective all rose steadily with their intellectual development. It seems that children do feel a strong connection to the buildings they experience.

General theories suggest that diversity, novelty or atypicality, produce complexity, which, in turn, affects arousal and preference. Studies of buildings and urban scenes have shown that increases in diversity lead to increases in interest (excitement) with people on balance preferring moderate levels of diversity. Order produces familiarity and there is a preference for this as well. The finding that people like both order and complexity may appear contradictory, but researchers agree with the model that: complexity catches the observer's attention and stimulates arousal; and order helps the observer make sense of it. Thus designs that offer order and related features should evoke pleasurable responses, and that pleasure can be heightened through a combination of order and familiarity with moderate complexity or atypicality (Sonnenfield 1966, Canter and Thorne 1972, Kaplan et al. 1976, Brower 1988).

Much work has been done when it comes to the colour impact on the built environment and occupants' perception. Read et al. (1999) consider that both colour and ceiling height affect children's cooperative behaviour.

Engelbrecht (2003) argues that the colour of walls in the classroom affects productivity and accuracy, while Brubaker (1998) argues that cool colours permit concentration. Bross and Jackson (1981) carried out a study on girls in grades 7-9 which found that the participants made fewer errors when working in cubicles painted in their preferred colour, while time to complete tasks changed minimally. Hamid and Newport (1989) concluded that pre-school children demonstrated more physical strength and a positive mood in a pink- coloured room than in a blue-coloured room.

In order to judge the impact of environmental colour on learning capacity, Henner Ertel, director of an institute for rational psychology in Munich, conducted a 3-year study among children (Henner 1973, Reported by Birren). Rooms with low ceilings were painted in different colours and it was found that the more popular colours were light blue, yellow, yellow green and orange. The use of these colours could raise IQ by as much as 12 points over environments where colours considered ugly - white, black and brown – were used. The popular colours also stimulated alertness and creativity, whereas white, black and brown playrooms made children less attentive. Orange, in particular, improves social behaviour, cheers the spirit and lessens hostility and irritability (Figure 37).

Studies of specific features have confirmed the preference associated with naturalness or a decrease in the prominence of built features (Herzog et al. 1982, Nasar 1984). For example, research found that the removal of utility poles, overhead wires, billboards and signs from photographs of roadside scenes produce increases in preference for the scenes. Water, particularly moving water, enhances scenic quality and the level of excitement (Winkel et al. 1970). In a Canadian study (Herrington et. al 2006) children spoke more with each other and for longer durations when they encountered worms or bugs. Likewise, contact with plants and animals can, not only enhance cognitive development, but encourage imaginative play and stimulate empathy.

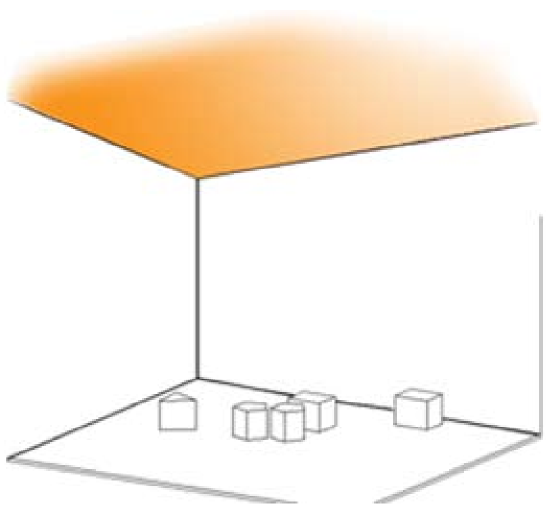


Figure 37: Orange improves the social behaviour; cheers the spirit and lessens hostility and irritation

3.3.1 Complexity

Theories suggest that diversity, novelty or atypicality, produce complexity, which, in turn, affects arousal and preference. The preference has held in a variety of contexts. It has shown stability for many places (Nasar 1998), U.S. and Japanese street scenes (Nasar 1984), architectural exteriors from around the world (Oostendorp and Berlyne 1978), buildings in relation to neighbouring buildings (Groat 1984), and buildings in relation to their natural settings (Wohlwill 1982).

One practical option stands out:

- ➔ Appearance: The architectural exterior (appearance) is the first impression of the school and presents a unique opportunity to inspire pupils and teachers.

Appearance

Diversity

Diversity can offer visual choices of shape and form. A regular box is not the only answer. Adjustments to the geometry of space can balance hard and soft forms, asymmetrical and symmetrical patters, creating visual and tactile interest. This raises another perspective – that of information processing (Kaplan and Kaplan 1989). This argues that because people have to find their way through the environment, cues that help people make sense of their surroundings become important. People like places that make sense and offer involvement. Features that increase involvement include diversity and the promise of further information ahead.

Hosmarinpuisto School and Day Care Centre is located in Espoo Finland. Long exterior eaves provide shelter from rain and large canopies give safe spaces for playing on the sides of the building. The architect (Yrjo Suonto) has adapted a highly expressive architectural form which can be interpreted as a dramatic reinvigoration of the

Figure 38: (Left) Two-story wood building with simple roof forms but sufficient detailing of fence, shading devices and long eaves to provide visual richness; (Right) Large canopies between the inside and outside increases the spatial experience and allow children to play safely on all sides of the building. (Hosmarinpuisto School and Day Care Centre, Espoo, Finland – Illustrative Case)

Figure 39: Liveable space: central courtyard where people can watch spaces with full of vitality and abundant information (Hosmarinpuisto School and Day Care Centre, Espoo, Finland – Illustrative Case)

strength and creative energy of students, staff and visitors (Figure 38).

In the courtyard, circulation is by a gangway around the perimeter, and by a wood and glass bridge that links the school to the cafeteria and office. The yard visually connects the upper and lower levels and provides a flexible gathering space, a communal centre, an outdoor play area and / or a space to relax (Figure 39). From Whyte's (1980) research, people are attracted to places – called liveable spaces – that have a view full of vitality and abundant information. The presence of people increases preferences for scenes, as people generally enjoy watching one another. Places to sit with such views always tend to attract people, as does activity.

Order

The preference for order and related variables has held in a variety of contexts. People's preference is often associated with increase in order and related variables, such as unity, coherence, clarity, compatibility and legibility. Features that may contribute to order include uniform texture, distinctive elements, focal point, low contrast (in the colour, size, texture, and shape of elements or between objects and their background), and replication of facade features (Wohlwill 1982, Groat 1984, Nasar 1987).

Kingsmead Primary School (Norwich, Cheshire, UK) is a single storey building (Figure 40). Its dynamic form is derived from its main structural elements, which are timber arches constructed from laminated and glued timber (glulam). The main facades appear light and generally

Figure 40: (Left) Timber on all the elevations gives a rustic and compatible character to the building; (Right) Winter garden and convex curved shape make it vivid, light and transparent. (Kingsmead Primary School, Norwich, Cheshire, UK - Illustrative Case) (Source: White Design Associates)

transparent, with the appearance of large glazing in aluminium panelling. On first view, timber has been used extensively and there appears to be a regular and ordered pattern to the façades' appearance, however, on closer inspection the façade treatment is complex, with convex curved shape, alternate large or small, outward and inward glazing which shift across the façade between the long eaves.

3.3.2 Colour

When discussing colour in an educational context, it is important to approach colour choices as a functional question rather than solely from the standpoint of aesthetics. Functional colour focuses on using colour to achieve an end result such as increased attention span and lower levels of eye fatigue. These colour schemes are not measured by criteria of beauty but rather by tangible evidence. For example, colour has been found to have an influence on blood pressure and behaviour.

Furthermore, colour psychologists have linked colour with brain development and the human transition from child to adult. Given its many impacts, appropriate colours can protect eyesight, create surroundings that are conducive to study and promote physical and mental health. Many cases of nervousness, irritability, lack of interest, and behavioural problems can be attributed directly to incorrect environmental conditions involving poorly planned light and colour. It is not enough to simply provide colour, through teacher's displays, school signs, and paint availability!

The location (inside, outside) of a colour can make a great deal of difference in influencing a building's character, the way it is perceived psychologically, and subsequent reactions to it. A particular hue that is perfectly suitable for an outside facade may elicit a different reaction when applied to the inside of a room. The same can happen when it comes to the colour themes for different functional spaces within the building. Therefore, two 'practical options' are emphasized here:

- ➔ Appearance: colour can directly affect an individual's impression of temperature, size of the object and distance of the space. Central to the impact of colour is the curvilinear issue of avoiding over or under stimulation through the degree of complexity or unity employed (Mahnke, 1996, p22-27).

- ➔ Rooms: when selecting colours the nature of the task is strongly relevant. When concentration is sought it can be assisted through the use of different colours, discriminating between those that are psychologically stimulating as opposed to physiologically stimulating. Appropriate colour schemes for particular rooms/functions will vary.

Appearance

The use of applied colour in architecture is treated with caution by many architects particularly when used on the external facades of new buildings. The designers of Xinzhou School in Suzhou, China (Figure 41) use quite strong colours on the facades, which are intended to reflect the pleasurable nature of attending daycare, and encourage children to accept that this is a building for play and creativity rather than tending to dwell on the more negative aspects of extended periods apart from

Figure 41: Warm to hot paired colours create an exuberant exterior (Xinzhou Kindergarten, Suzhou, China - Illustrative Case)

their parents; in this respect it is a welcome distraction. However and perhaps more importantly, the colours are used to counter the prevailing climatic conditions, where the high humidity and hot climate can often promote listlessness amongst staff and children. Here, colour is used to counter this negative energy by stimulating the senses, with warm to hot paired colours.

In contrast, Jubilee Primary School in London tells another story. Sustainability and low energy design were key objectives of the design team. The building employs a range of design features including natural ventilation via wind chimneys, natural lighting, a green roof planted with sedum and an insulation material made from recycled newspaper.

However, the public face of the building is at first sight austere. From the street it is a box-like, high structure, handsomely finished predominantly in white render; this is an architectural language which is not to everyone's taste (Figure 42). 'It looks more like a supermarket than a school' was one comment and 'it's ugly' was another (Dudek 2005). It is often argued that white is an ideal neutral colour. However, the impact of a white built environment on people tend to be under-stimulation. Persons subjected to under-stimulation show symptoms

Figure 42: (Left) Main entrance; (Right) Nursery entrance (Jubilee School, Brixton, London, UK - Illustrative Case)

of restlessness, excessive response, and difficulty in concentration. Such environments, in fact, are anything but neutral in the effects they have on their occupants.

Rooms

People can seek to design environments that serve a specific function, and it makes a difference how colour is used. However, it is not as simple as trying to create a stimulus that only calls forth a physiological reaction of some type. When designing with colour, it has to be seen in the context of the whole design and not slavishly applied through generalities. The information below effectively sets out a pallet of possible effects that needs to be wielded with sensitivity and finesse.

In choosing appropriate surface colours, much depends on the specific hue, its value and intensity. Also, where colour is placed, how much of it, for what purpose, and for what length of time, should all be taken into account? (see *Appendix* for more information) It is clear that any strong colour will cause an immediate reaction that can be physiologically measured. However, the duration of the effect is not continuous. For example, red may increase the blood pressure, but after a length of time the body will normalize the condition, or even show an opposite effect. (Hope and Margaret 1990)

It is often argued that white, grey and even black are an ideal background to set off coloured decorative effects. Regardless of accent colour distribution, the main impression of the environment will more likely remain neutral. Also, persons subjected to understimulaiton show symptoms of restlessness, excessive response, and difficulty in concentration. Such environments, in fact, are anything but neutral in the effects they have on their occupants.

Another line of research that relates to colour is concerned with age issues. Heinrich carried out psychological colour tests on ten thousand children from 5-19 across the world (Figure 43). Heinrich's findings indicate which

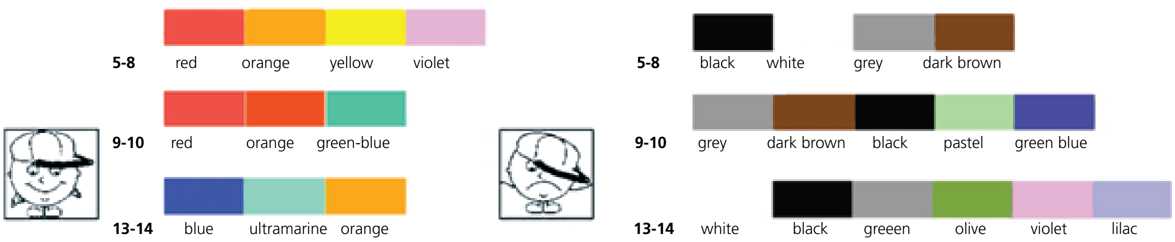


Figure 43: Rejected and accepted colours for children with different ages

colours might be best suited for different age groups in the school environment. Figure 43 is part of the results, indicating a difference between each age group (Heinrich 1980, Heinrich 1992).

In general, Heinrich found that black, white, grey, and dark brown were rejected by children between the ages of five and eight; red, orange, yellow, and violet were preferred. At ages nine and ten, grey, dark brown, black, pastel green, and blue were rejected. Preferred were red, red-orange, and green-blue. The 11-12 year-olds rejected achromatic (white, black, grey), olive, violet, and lilac. Preferences of the 13-14 year age group were blue, ultramarine, and orange. Heinrich is the first to point out the difficulty of using preferred colours, as determined in the tests. They are not always suitable as wall paints and must also be considered together with other factors, such as visual ergonomics.

The above discussion gives some indication of the range and depth of the research evidence on colour impacts and human sense perception. Based on these research works, Mahnke (1996) made some suggestions about applying these findings holistically to achieve optimal learning design solutions in different parts of schools.

Figure 44: Learning and playing, a space for nursery (Top) and elementary grades (Bottom) (Harlequin Kindergarten, East Kilbride, UK - Illustrative Case)

Learning spaces for nursery and elementary grades

Children of kindergarten through elementary-school ages are mostly extroverted by nature. A warm, bright colour scheme complements this tendency, thereby reducing tension, nervousness, and anxiety; colour may be light salmon, soft, warm yellow, pale yellow-orange, coral and peach. Colours of opposite temperature should also be introduced as accents. Under no circumstances should it be believed that by pinning drawings, cartoons or the like on the wall, the child's need for changes in hue, colour intensity, and lightness, is satisfied, or that it will reduce a monotonous room experience (Figure 44).

Learning spaces for upper grades

Softer surroundings created by subtle and/or cooler hues have centripetal action, which enhances the ability to concentrate by providing a passive effect. Side and back walls may be beige, sandstone, or light tan. However, Engelbrecht (2003) suggests that in classrooms where students face one direction the end wall of the classroom, behind the teacher, should be a different colour from the other walls. This idea is also offered by Pile (1997) and Brubaker (1998). Thus, this wall might be in medium tones of green or blue. The purpose of this is to relax the students' eyes when they look up from their tasks, thus providing effective contrast with chalkboard, materials displayed, training aids, and the instructor, as well as drawing attention to the front of the room by adding interest to the classroom through a different appearance from different direction, visual monotony is avoided (Figure 45).

- Subtle hues are used to enhance the ability to concentrate;
- Beige, pale or light green and blue-green are appropriate;
- The front wall's colour is different from the side

Figure 45: An example of the classroom for upper grade

and back walls (relax the eyes, provide effective contrast, draw attention);

- Side and back walls may be beige, sandstone, or light tan;
- The front wall might be in medium tones of green or blue.

Library and/or reading room

Pale or light green creates a passive effect that enhances quietness and concentration. (Figure 46)

Figure 46: Library with pale green carpet (Seoul Foreign Elementary School, Seoul, Korea - Illustrative Case)

Corridors and hallways

More colour range is possible in hallways. Colour schemes should be attractive and give the school a distinctive personality. In the lower grades hues may be lively; in a multi-storeyed school each corridor can be treated differently. Complementary colour schemes are quite appropriate. For example, light-orange walls offset with blue doors; or a light-green wall with lower-chroma red doors (not the tone of fire doors). (Figure 47)

- Present distinctive personality.
- Each corridor can be treated differently in a multi-storey school.
- Complementary colour schemes are quite appropriate; light-orange walls with blue doors; or a light-green wall with lower-chroma red doors.

Administrative offices

In colour specification, there are those that should not be used as dominant (wall) colours: no purple, violet, vivid yellow, yellow-green, bright red, and no white or grey. Beyond that the choice of hues, guided by good judgement, is fairly broad. In offices where intense concentration is required, attention should be directed inward with cool hues. In general office areas, the choice of warm or cool hues depends on preference. Soft yellow, sandstone, pale gold, pale orange, pale green and blue-green are appropriate (Figure 48).

Figure 47: The hallway with curved and blue wall gives a distinct feeling (Temple Primary School, Manchester, UK - Confirmatory Case).

- Where intense concentration is required, attention should be directed inward with cool hues.
- Elsewhere, soft yellow, sandstone, pale gold, pale orange, pale green, and blue-green are appropriate.

Cafeterias

Cafeterias may be a bit brighter than other spaces, although colour should not be intense and aggressive. Light red-orange, light orange, pale yellow, warm yellow, apricot, and pale green are good dominant wall

Figure 48: Headteacher office (Modular Building of School District 30, Northbrook, Illinois. Photo courtesy of the Modular Building Institute. US – Illustrative Case)

colours (yellow should not be too bright); some-what stronger for accents are blue and bluegreen. Laminated tabletops may be in wood grain or the colours specified as appetite colours, such as warm red, oranges, warm yellow, clear green. For purposes of cleanliness, floors should not be too dark (textures and patterns may conceal stains) (Figure 49).

- A bit brighter but not intense and aggressive
- Light red-orange, light orange, pale yellow, warm yellow, apricot, and pale green are good dominant wall colours (yellow should not be too bright);
- Somewhat stronger for accents are blue and blue green.
- Laminated tabletops may be in wood grain or the colours specified as appetite colours, such as warm red, oranges, warm yellow, clear green.
- Floors should not be too dark; texture and pattern may conceal unremovable strains.

3.3.3 Texture

Nasar (1984) found that people normally perceive two styles of environment as having distinct features from one another: natural (soft) elements, such as flowers, plants, grass and water; and obtrusive built (hard) elements, such as intense land use, high style building and busy traffic etc. The preference for the addition of nature and for natural over built scenes has amassed consistent empirical support. Studies of specific features have confirmed the preference associated with naturalness and a decrease in the prominence of built features.

People have a 'natural' positive response to texture as well as a desire to make built features. Built features enable people to identify or create order. They are visually rewarding in simultaneously possessing diversity and unity. 'Soft' texture animates landscapes and enables people to connect what they see with their sense of touch, as texture, like colour, provides unity and diversity in the surface of forms.

Texture can be manipulated in scale from coarse to fine and can be used in juxtaposition or in gradients from rough to smooth, for example, from a branch of red flowers to a piece of green glazing (Dee 2001).

Here, one pratical option stands out:

➔ Outdoors: Research indicates that the quality of life in a school is much enhanced when an abundance of useable outdoor space is present. The variety can add to the aesthetic appeal of places, enhanced as environmental conditions change with the seasons. There are also many practical applications, such as encouraging children's interest in thinking and asking; promoting the goals of recreational activities; enhancing physical and cognitive development; encouraging imaginative play, and stimulating empathy.

Outdoors

Covered areas can be looked as a transition from the school inside to the outside, from an enclosed space to a natural openness. Weather-protected transition spaces include porches and decks a minimum of two metres in depth that can serve as learning and playing spaces in their own right. From the POE surveys, the covered area between the inside and outside is always one of the

Figure 49: Cafeteria (Ditson Elementary School, Billerica, Massachusetts, US - Illustrative Case)

Figure 50: (Left) The rain-fall steps where water flows are used to foster this curiosity and sensitivity in the young learner; (Right) When the space is not used (Shirokane Kindergarten, Tokyo, Japan - Illustrative Case)

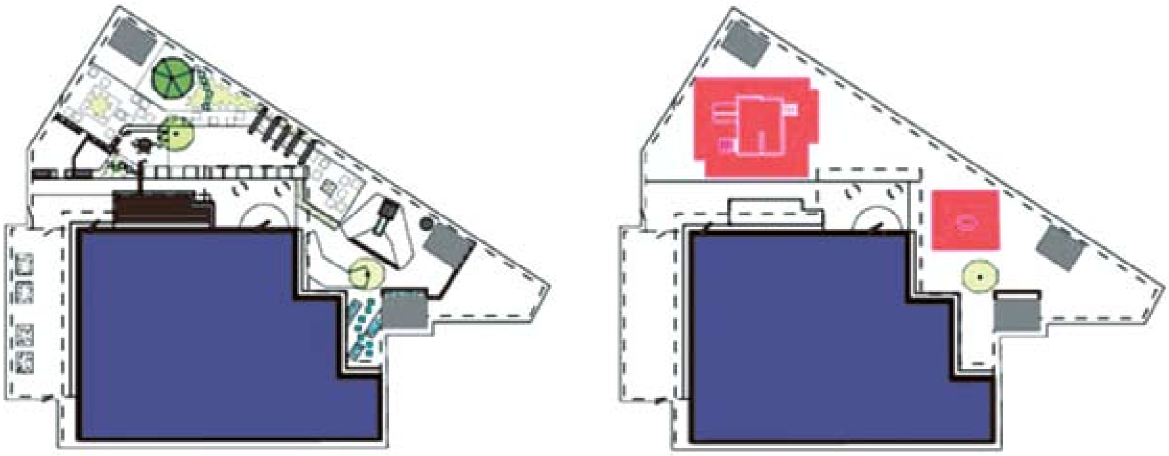


Figure 51: Plan views of the same play space (Left: The design offers manipulable materials and settings for children; Right: The design has only standardized play areas and rubber matting that offers less change and challenge)

children's favourite places.

In the case of Shirokane Kindergarten (Tokyo, Japan), there is a half covered plaza at the corner, which is expressed architecturally as a natural extension of the building's form. Children can move back and forth freely between the building, plaza and playground.

On a rainy day, the pupils can be active on the wooden steps. During class time, these spaces become a place of serenity, where children learn about tradition and manners. Various design ideas have been introduced so that children can experience the wonders of seasonal and weather changes, and through the usage of these elements children can stimulate and develop their natural abilities, such as receptivity, imagination and vitality (Figure 50).

Taking all research collectively, it is safe to suggest that fabric variety is psychologically the most beneficial. One reason is that normal consciousness, perception and thought can be maintained only in a changing environment. When there is no change, a state of 'sensory deprivation' occurs, which means that the capacity of people to concentrate deteriorates, attention fluctuates and normal perception fades.

Therefore, spaces outside and adjacent to the school buildings can be used for more than simply 'burning off energy'. In terms of the texture design of the school building and its landscape, the balance between unit and complexity is a very important rule in the design of a beneficial environment.

At present, many outdoor spaces in schools are dominated by playsets, such as climbing frames, turning pars, balance beams and /or overhead ladder. Early childhood educators and children are less likely to take ownership of these standardized play space.

While many outdoor play spaces are characterised by asphalt, they can potentially incorporating manipulable materials like sand, dirt, gravel, mud, plants, pathways and water into a play space, which can powerfully express seasonal cycles. Varied outdoor elements offer more developmental and play opportunities than spaces that did not contain these elements (Figure 51). They easily allow children to exert control over their play space and change their surroundings to suit their needs. Children want to play with responsive materials that can be carried, collected, damned, dug, floated, filled, scooped, sifted, spilled, sprinkled, and thrown.

Lumin Primary School is a private primary school located within the urban mix of Yantai, Shandong, China (Figure 52). The school's mission is to provide more creative outdoor opportunities and displays a comprehensive design integrated into the existing school buildings to provide pupils with a supportive atmosphere where they can build self-confidence, develop a love of learning, succeed in their studies and build toward their futures.

The design touched upon every usable square foot of school property to maximize the pupils' educational experience and improve school circulation within the urban constraints of the site. To maximize the chance of year-round use of parts of the outdoors, design elements include all kinds of sports and / or ball field, track, game playground, sand play, trails, garden, small pet house, ponds and climbing wall etc., which create favourable microclimates and allow for a variety of learning activities and experiences not available indoors.

1 building
2 pavilion
3 central play spaces
4 aquatic plants
5 outdoor classroom
6 game play
7 wooden playset
8 pergola
9 sand exploration
10 small pet house
11 seat wall
12 ball court
13 climbing wall
14 water play

Figure 52: Part of the outdoor design (Lumin Primary School, Yantai, Shandong, China - Confirmatory Case)

4 Summary

Having set out the principles and elements that should inform the design of optimal learning spaces at the start of this report, it is hoped that it can now be seen, through the cases given, that these principles can be operationalised in school designs.

By focusing on enhancing the learning of school pupils, successful designs will exhibit some combination of the set of practical design features summarised in Table 3. To make this useful in the design process these are structured using the "practical options" axis in Table 1.

The challenge is, of course, to create a coherent design in a specific place for particular people, in which these features reinforce each other and positively support the experience of pupils and staff.

It can be seen that the themes of (positive) naturalness, individualisation and appropriate (low in some places – higher in others) levels of stimulation pervade this report. It is also evident that complex practical issues are addressed alongside compounding psychological and sociological issues associated with spaces, such as status, control and social belonging (Vischer 2005). Although, or perhaps because, this report is centred on young children, it can be argued that the needs addressed represent a raw exposition of universal human needs.

The emerging approach gives prominence to addressing fundamental users' needs through an explicitly designed approach to human sense inputs. This provides a tremendous challenge for designers to understand how these underlying human goals may be enabled, whilst also creating dynamic solutions that can accommodate significant variations in users' needs, both at any point in time and over time.

This report provides and illustrates a range of possible practical responses to a broad set of design parameters. Though these individual strategies can improve a school's building performance, only through whole-building analysis and integrated design can the positive impact of the built environment on pupils' attainment and well-being be maximised. We hope that school clients and designers are stimulated to take these ideas into their practice and to experiment with them.

At this point, how to integrate the design opportunities raised here deserves more attention in future research work. It is anticipated that this will be achieved through the study of practical applications, which will, in addition, provide a window on the interactive impacts of different sense experiences – a further aspect that we hope to inform through additional theoretical work.

Table 3: Design for school pupils linked to design parameters

Practical option	Description *[Page No.]*	Design Parameters
Location	School location is suggested witthout any obstruction surrounded, such as buildings and trees because it may cast too much shadow in the daytime. *[8]*	Light
	School site is away from the busy roads. Open areas and trees can be used as a buffer-zone to give acoustic separation. *[8]*	Sound
	Located in a well-defined neighbourhood, the school can reach the communities and facilities easily and conveniently so that it might take advantage of the local community's existing neighbourhood resources. *[23]*	Connection
Orientation	Classroom windows face the south-east or south-west and classrooms are so sited in relation to external obstructions that a minimum of 2 hours duration of penetration is obtained. *[5]*	Light
	The south rooms can heat up quickly, especially when the sunlight directly penetrates into the room. While the rooms towards the west experience stronger and more intense sunlight and sun heat than those towards the east. The north rooms do not receive direct solar radiation for most of the time. *[10]*	Temperature
	School to be located as much distance as possible from the source and also in the windward side in terms of the local predominant wind direction. *[12]*	Air quality
	Kitchen and cafeteria should be located towards the leeward sides in terms of the local predominant wind direction, so that the food smell can be avoided as a disturbance to the whole school building. *[13]*	Air quality
Layout	The sensitive space or room can be carefully located and separated from intruding noise both from the outdoors and from within the building. *[9]*	Sound
	The toilet and corridor act as a buffer zone to give acoustic separation. *[9]*	Sound
	A compact and simple plan is always better than a spread-out and complicated arrangement. The more complex the form may result in more heat loss with more exposed surface and less heat gain due to self-shadowing. *[10]*	Temperature

Optimal Learning Spaces

Design Implications for Primary Schools

Practical option	Description *[Page No.]*	Design Parameters
Appearance	School elevation with diversity (novelty) catches the pupils' attention and arousal; and order (familiarity) helps the pupils make sense of it. A combination of order with moderate diversity can achieve pleasurable responses. *[25]*	Complexity
	People's preference is often associated with increase in order and related variables, such as unity, coherence, clarity, compatibility and legibility. *[26]*	Complexity
	Strong colours on the facades can reflect the pleasurable nature of attending daycare. Also the colours can be used to counter the prevailing climatic conditions by stimulating the senses, with warm to hot paired colours. *[27]*	Colour
Windows	Windows are heads close to the ceiling in order to receive an amount of skylight and solar heat. A glazing ratio (glazing area/wall area) of 40% is recommended for south, east and west facing windows, 55% is for north facing ones. Small windows at the top can allow circulation but not draught. *[6]*	Light
	Clerestory windows admit light deep towards the back of the room and henceforth create a more uniform daylight distribution throughout if there is another side window. *[7]*	Light
	The larger the window the more the solar gain and the greater the heat loss. Therefore, the glazing with a low U-value is preferred for schools. *[10]*	Temperature
	Windows have to be carefully designed to allow for different weather conditions Windows (doors) are located on opposite side for cross ventilation. *[13]*	Air quality
	For child-centred spaces, windows can be smaller and heights lower to accommodate children. It not only minimizes the institutional character of buildings but also creates more intimate spaces. *[16]*	Choice
Rooms	Absorbents on classrooms ceilings can reduce reverberation and can damp out the most annoying components of impact sound. *[9]*	Sound
	The stage is placed on the long side of the hall- the source of sound is not far from the fathest listener. Curtains and moveable screens with sound-absorbent surfaces can be used in order to change the sound characteristics of the area. *[9]*	Sound
	Spaces with varied heights can create liveable gathering places. Usually places to sit with views of others tend to attract people, as does activity. *[15]*	Choice
	For child centred spaces, elements and spaces can be smaller and heights lower to accommodate children. *[16]*	Choice
	To maximize the flexibility of instructional clusters, it is very useful to provide a space especially for shared activity. The teachers can have break-out groups anytime as this space is always available. *[18]*	Flexibility
	There is widespread popular belief that smaller classes are better. Children are settled and secure, they are more engaged and interested in their education. *[18]*	Flexibility
	'L' shaped classroom is a design patter that offers teachers options in how they might organize their classrooms to facilitate the development of their students in various learning activity. *[20]*	Flexibility
	When selecting colours the nature of the task is relevant. Classrooms, corridor, library and cafeteria all sever different functions; therefore their colour scheme has to be treated differently. *[29-30]*	Colour
Circulation	The circulation pattern should be clear and direct, covering all levels from access to the buildings to local circulation between spaces. Visually engaging paths with easily identifiable destinations transform aimless wandering into purposeful walking, thus encouraging people to move around the school safely and independently. *[21]*	Connection
	Creating central activity nodes (breakout spaces) can increase opportunities for project-based learning, small group instruction and positive social interaction. *[22]*	Connection
Ourdoors	It should be weather-protected. This transition space includes porches and decks with a minimum of six feet in depth that can serve as learning and playing spaces in their own right. *[31]*	Texture
	Planted school yards powerfully express seasonal cycles. With ample and change movement it has positive effects on learning and cognitive qualities. *[32]*	Texture
	Texture variety is psychologically the most beneficial as it avoids the 'sensory deprivation'. The outdoor should be designed with a variety of learning activities and experiences, such as trails, gardens, fields, forested areas, ponds and other natural outdoor learning settings. *[33]*	Texture

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Appendix: General Impact of Colour in Spaces

There are many tried and tested ways to use colour in space, based on how colours contrast with or enhance one another, how colour temperatures are juxtaposed, and how well our eyes are willing to accept optical tricks. The statements that follow are a few of the most common observations about decorative colour.

- Colours look stronger in large areas than in small areas. Therefore, the larger the space, the lighter or more neutral the colour should be. Brightness increases as surface size decreases.

- Colours are affected by their adjoining colours. A medium-toned colour looks darker against a light colour than against a dark colour. The reverse also holds true.

- Warm colours are more suitable for rooms with northern exposures, as they simulate sunshine; cool colours counteract the warmth of a sun-filled room.

- Light colours make small rooms look larger; dark colours make large rooms look smaller.

- Simple colours are recommended on elaborate forms and vice versa.

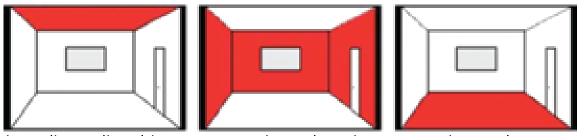
People can design environments that serve a specific function, and it makes a difference how to use colour, but it does not work through the method of trying to create a stimulus that only calls forth a physiological reaction of some type. When designing with colour, people have to see it in context, and not apply it through generalities. Although it might work in some cases, each particular situation needs to be analyzed individually to see generalities pertain.

In choosing appropriate surface colours, much depends on the specific hue, its value and intensity. Also, where colour is placed, how much of it, for what purpose, and for what length of time should all be taken into account? It is clear that any strong colour will cause an immediate reaction that can be physiologically measured. However, the duration of the effect is not continuous. For example, red may increase the blood pressure, but after a length of time the body will normalize the condition, or even show an opposite effect. (Hope and Margaret 1990)

Here are some typical examples of how typical hues and their location (top, bottom and sides) can make a great deal of difference in influencing a room's character and its impact on people's sensation and perception.

In practical situations, pure red is seldom used as the dominant colour, but more as an accent. Although physiological arousal may be temporary, red psychologically exhibits emphatic characteristics. Therefore, the overuse of saturated red adds to the complexity within a space. Modifications of pure red are much more suitable.

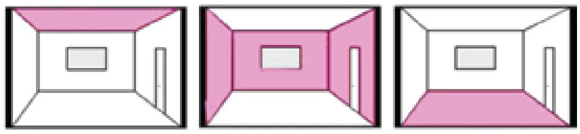
*What **RED** can do?*



intruding, disturbing, heavy | *aggressive, advancing* | *conscious, alert, perhaps pompous*

Pink must be handled carefully. It is generally considered feminine, therefore usable in spaces considered to be in the intimate feminine sphere. Typically it is considered perfect for a young girl's bedroom (pink for girls, blue for boys), but it has become quite a cliché. As an alternative, light blue-green as a dominant colour may be used for both genders, but accents can tip the scale in favour of feminine or masculine. With pink much depends on the exact nuance used; a bubblegum pink will be much livelier and somewhat cheaper-looking than an elegant old rose.

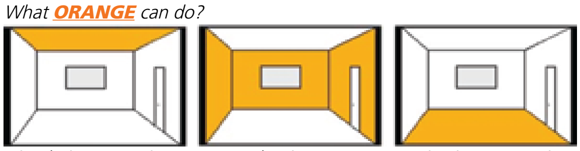
*What **PINK** can do?*



delicate, comforting | *aggresion-inhibiting, too sweet if not greyed down* | *perhaps too delicate, unfamiliar in this location*

Orange is more mellow than red and is easier to live with. But if it is too bright, it can hardly be used as anything other than an accent. Pastel orange is appropriated to set cheerful, lively, and sociable moods. In its reflection on skin it may enhance some complexions, especially when its hue position is close to peach (making it an appropriate colour in the bathroom or toilet).

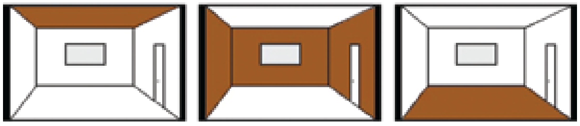
*What **ORANGE** can do?*



stimulating, attention-seeking | *warm, luminous* | *activating, motion-orientated*

There is a great difference between the browns of natural materials such as wood and brown paint. Brown as a paint is never as comfortable-looking or warm as wood. Brown paint should not be used in certain institutions so as not to evoke faecal associations.

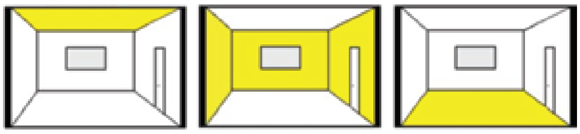
*What **BROWN** can do?*



oppessive and heavy (if dark) | *secure and assuring if wood; much less so if painted* | *steady, stable*

Because of its high visibility, yellow serves many safety purposes, especially in industrial environments. It also appears brighter than white and is useful in poorly illuminated and dim spaces. Pastel yellow can be harmonized with many accent colours, thereby enlivening a space in its predominant mood-cheering and friendly flavour. The accents may then push it toward being either more exciting and warmer (orange, red), or cooler and more calming (green, blue-green).

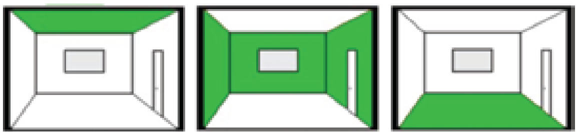
*What **YELLOW** can do?*



light (if toward lemon), luminous, stimulating | *warm (if toward orange), exciting to irritating (if highly saturated)* | *elevating, diverting*

Green, along with blue-green, provides a good background environment for meditation and tasks involving concentration.

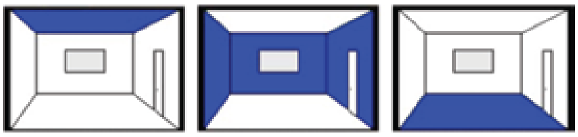
*What **GREEN** can do?*



protective (reflection on skin can be unattactive) | *cool, secure, calm, reliable, passive, irritating if glaring (electric green), muddy if toward olive* | *natural (up to a certain saturation point), soft, relaxing, cold (if toward blue-green)*

Blue tends to be cold and bleak if applied to large areas, especially in hallways and long corridors, and certainly when it is light. Medium or deep tones are appropriate in incidental areas. Pale blue is refracted sharply by the lens of the eye and therefore tends to cast a haze over details and objects in the environment. This may cause distress to some people confined to a particular area for a long period.

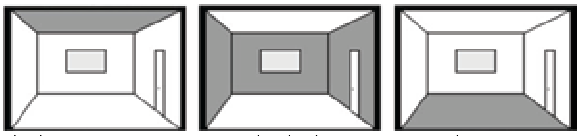
*What **BLUE** can do?*



celestial, cool, less tangibly advancing (if light), heavy and oppressive (if dark) | *cool and distant (if light), encouraging and space-deepening (if dark)* | *inspiring feeling of effortless movement (if light), substantial (if dark)*

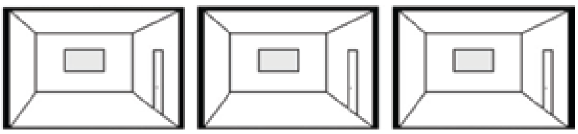
It is often argued that white, grey and even black are an ideal background to set off coloured decorative effects. Regardless of accent colour distribution, the main impression of the environment more likely will remain neutral. Also, people subjected to understimulaiton show symptoms of restlessness, excessive response, and difficulty in concentration. Such environments, in fact, are anything but neutral in the effects they have on their occupants.

*What **GREY** can do?*



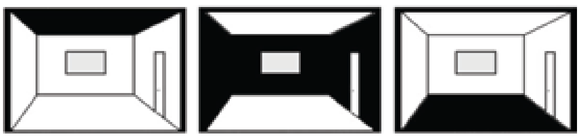
shadowy | *neutral to boring* | *neutral*

*What **WHITE** can do?*



empty, no design objections - helps to diffuse light sources and reduce shadows | *neutral to empty, sterile, without energy* | *touching-inhibiting (not to be walked upon)*

*What **BLACK** can do?*



hollow to oppressive | *ominous, dungeon-like* | *odd, abstract*

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Figure 29: CABE/A&M, http://www.cabe.org.uk/case-studies/redbrook-hayes?photos=true (ac cessed on 15 Sep. 09)

* Figure 30: (Modified) Franklin Hill; Patterns for Small Learning Communties at the Elementary Level: The "L" Shaped Classroom (2008), p5 (http://www.schoolfacilities.com/uploads/files/85.pdf (accessed on 15 Sep. 09))

Figure 31: The Architectural Partnership, The Sharp Building, 206 south 13th ST. STE. 906, Lincoln, NE 68508, http://www.taparch.com/

Figure 32: (Modified) http://www.kingsmead.cheshire.sch.uk/virtualtour/vt.html (accessed on 15 Sep. 09)

Figure 33: http://www.kingsmead.cheshire.sch.uk/virtualtour/vt.html (accessed on 15 Sep. 09)

* Figure 34: (Modified) http://www.designshare.com/index.php/projects/west-haven-elementary/im ages (accessed on 15 Sep. 09)

Figure 35: http://www.farnboroughgrange.hants.sch.uk/ (accessed on 15 Sep. 09)

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* Figure 38: PEB Compedium of exemplary educatonal facilities 3rd edition (p27 up; p24)

* Figure 39: PEB Compedium of exemplary educatonal facilities 3rd edition (p25)

Figure 40: (Left) White Design Associates, 101 Sevier Street, Bristol, BS2 9LB, UK

Figure 40: (Right) http://www.kingsmead.cheshire.sch.uk/virtualtour/vt.html (accessed on 15 Sep. 09)

* Figure 41: http://www.xinzhou-sz.com/index.asp (accessed on 15 Sep. 09)

* Figure 42: Dudek Mark, Schools and Kindergartens a design manual (P151 left and middle)

Figure 43: SCRI, University of Salford, 4th Floor, Maxwell Building, Salford, M14 5WT, UK

Figure 44: http://www.harlequinkindergarten.org.uk/ (accessed on 15 Sep. 09)

Figure 45: SCRI, University of Salford, 4th Floor, Maxwell Building, Salford, M14 5WT, UK

Figure 46: http://www.sfs.or.kr/elementary/eslibrary.html (accessed on 15 Sep. 09)

Figure 47: SCRI, University of Salford, 4th Floor, Maxwell Building, Salford, M14 5WT, UK

Figure 48: http://www.modular.org/Magazine/savemoney02_03.aspx (accessed on 15 Sep. 09) (photo courtesy of the Modular Building Institute. US)

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* Figure 50: PEB Compedium of exemplary educatonal facilities 3rd edition (p88,89)

* Figure 51: Susan Herrington, An informational guide to young children's outdoor play spaces 7Cs p34

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Comments on this Report from Experts

"This report is a first of its kind - a thoughtful and thorough reflection on the essential link between school environment and the brains and minds of those who study and learn there. Systematically applying Neuroscience knowledge to practical design know-how, as this report superbly demonstrates, is the surest way to guarantee school designs that support brain development. The neuro-architecture and neuro-interiors that result from this essential linkage represent the best application imaginable of this new paradigm."

***John Zeisel**, PhD, President and co-founder of Hearthstone Alzheimer Care and author of "Inquiry by Design" and "I'm Still Here"*

"The perception of the physical environment is a complex matter, and designing for it is never easy. In a very practical and useful evidence-based guide this SCRI Report provides valuable advice for creating places where children, students and teachers might actually want to be. Focused towards primary schools, much of it is equally useful for other school environments too."

***Alastair Blyth**, Analyst, Centre for Effective Learning Environments, OECD*

"The work that we are doing with Salford has the potential to transform the design process and ensure the environment we create is truly fit for purpose. It will challenge the way we assess designs - particularly at the early stages of the process. It may well prove to be the most significant built environment research project we have been involved in."

***John Lorimer**, Capital Programme Director, Manchester City Council*

"This timely report will help with the important task of defining what delivers value in a school building. Higher pupil achievement is linked to appropriate design and that is worth a lot. The three identified drivers of response, naturalness, individualization and stimulation, are good axes on which to organize ideas. Seeing the school building as 'silent curriculum' should also be very helpful to educators: our unconscious responses to environment is made clear. The building can also teach sustainability: how man-made things work with nature, and how they are designed and made."

***Richard Saxon**,CBE, former director of the Building Design Partnership and author of the Constructing Excellence report "Be Valuable"*

"If you are involved in the design of school buildings, an essential reading is Optimal Learning Spaces: Design implications for Primary Schools. Naturalness, individualisation and level of stimulation are the three defining principles identified through a review of research evidence on people's response to environmental stimuli. Highly illustrated with photographs and diagrams, the report aims to help readers understand and apply each design concept. Newly built and refurbished primary schools should be considerably improved through application of the knowledge contained in this guide."

***Alexi Marmot, Director**, AMA Alexi Marmot Associates and Professor of Facility and Environment Management, Bartlett School of Graduate Studies, University College London.*

"This is the most important construction research report I have ever read. The research clearly demonstrates the value of defined elements of good design in creating the best school environments. The goal of creating learning environments that enhance performance is not just one that is critical to the education sector, it is fundamental to every commercial organisation in the world. If the results of research into the value of design aspects can be translated into other sectors such as office environments it will fundamentally transform architecture and the way we make all places."

***Chris Woods**, Research and Development Director, Wates Group*

"The design requirements for primary schools are not well understood, even though most school boards have formulas based on previous designs. This report provides criteria (and the associated background studies related to the criteria) that can be used by educators and their architects in developing satisfactory schools. Eventually if we are to truly understand such themes as naturalness, individualisation, and appropriate levels of stimulation we need to undertake more research at the level of the brain and the mind and to tie this knowledge to the impacts of different sense experiences."

***John P. Eberhard**, Founding President of the Academy of Neuroscience for Architecture and former Director of the Institute for Applied Technology at the National Bureau of Standards and President of the AIA Research Corporation. Also author of "Brain Landscape: The Coexistence of Neuroscience and Architecture".*

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