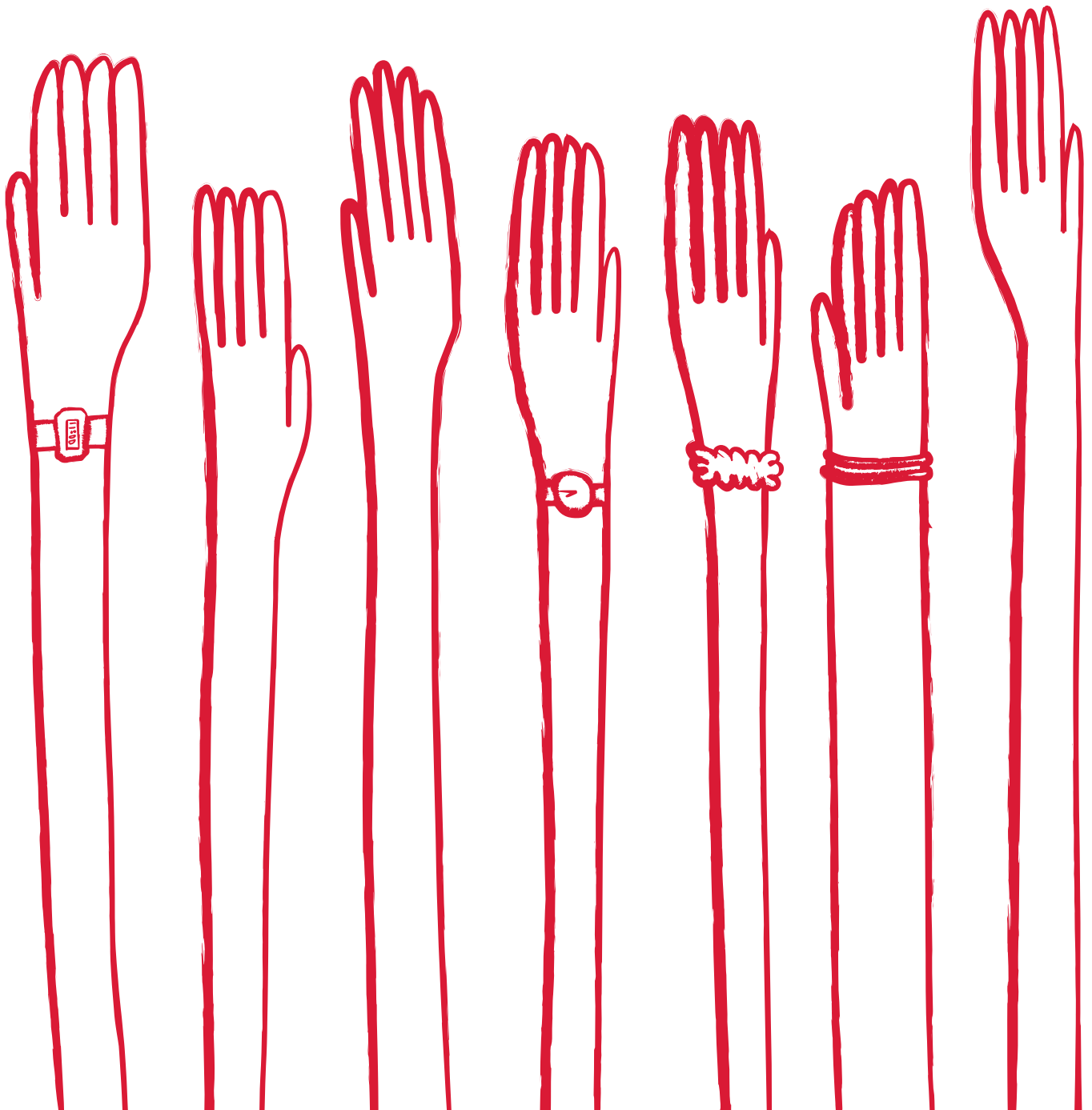# University of Salford
MANCHESTER

Clever Classrooms

Summary report of the HEAD Project
(Holistic Evidence and Design)

Professor Peter Barrett
Dr Yufan Zhang
Dr Fay Davies
Dr Lucinda Barrett

Based on the results of the **HEAD Project** *(Holistic Evidence and Design)*, funded by the Engineering and Physical Sciences Research Council, clear evidence has been found that well-designed primary schools boost children's academic performance in reading, writing and maths. Differences in the physical characteristics of classrooms explain 16% of the variation in learning progress over a year for the 3766 pupils included in the study. Or to make this more tangible, it is estimated that the impact of moving an 'average' child from the least effective to the most effective space would be around 1.3 sub-levels, a big impact when pupils typically make 2 sub-levels progress a year.

This is the first time that clear evidence of the effect on users of the overall design of the physical learning space has been isolated in real life situations. Specific aspects have been studied in the past, such as air quality, but how it all comes together for real people in real spaces has proved to be a knotty problem.

In this context the researchers on the HEAD project worked for the last three years, carrying out detailed surveys of 153 classrooms from 27 very diverse schools and collecting performance statistics for the pupils studying in those spaces. The success of the study comes from taking into account a wide range of sensory factors and using multilevel statistical modeling to isolate the effects of classroom design from the influences of other factors, such as the pupils themselves and their teachers.

Three types of physical characteristic of the classrooms were assessed: Stimulation, Individualisation and Naturalness, or more memorably the SIN design principles. The factors found to be particularly influential are, in order of influence:

- Naturalness: light, temperature and air quality – accounting for half the learning impact
- Individualisation: ownership and flexibility – accounting for about a quarter
- Stimulation (appropriate level of): complexity and colour – again about a quarter.

The twenty-page core of this report takes each of the individual aspects above and provides more detail on the results, linked to practical advice for designers and teachers. Within this it is interesting to note that the aspects linked to the appropriate level of stimulation for learning is curvilinear – neither chaotic, nor boring, but somewhere in the middle.

Surprisingly, whole-school factors (eg size, navigation routes, specialist facilities, play facilities) do not seem to be anywhere near as important as the design of the individual classrooms. This point is reinforced by clear evidence that it is quite typical to have a mix of more and less effective classrooms in the same school. The message is that, first and foremost, each classroom has to be well designed.

A very positive finding is that users (teachers) can readily action many of the factors. The suggestions included show that small changes, costing very little or nothing, can make a real difference. For example, changing the layout of the room, the choices of display, or colour of the walls.

We hope that designers, involved in creating new or making alterations to primary schools, and teaching professionals, acting as clients or deciding how use their teaching spaces, will find the evidence presented here stimulating and useful.

Acknowledgements

Contents

The core of the report is in Sections 4 and 5.

Section 4 gives details of the main, overall, findings.

Section 5 then takes each of ten factors into more detail and provides check points for designers and teachers to consider.

To contextualise these findings:

Section 1 highlights the challenge being addressed, typified by a current lack of evidence.

Section 2 sets out how this study has sought to move past the barriers to creating that evidence.

Section 3 gives details of the extensive and diverse data collected and analysed.

Lastly,

Section 6 & 7 provides some overall conclusions and summary checklists of issues for designers and teachers to consider.

The challenge

Intuitively most people would probably feel that the design of the spaces we live and work in does make a difference to how we feel and, in turn, may well affect how well we perform the activities in which we are engaged. Oddly this is not currently supported by a strong or actionable evidence base.

Internal environment quality (IEQ) research has understandably focused on the readily measurable aspects of: heat, light, sound and air quality. So quite a bit is known about individual aspects, say, the impact of air quality on concentration levels, usually rooted in controlled laboratory studies, but at times extended to the classroom situation (Bakó-Biró, Clements-Croome, Kochhar et al. 2012). Some aspects have gained traction, for example Ulrich's (1984) classic evidence of the positive healing effects of views of nature in the hospital environment.

What has been more problematic is to address all the factors impacting on a person, in a real space, and at the same time. This raises issues of scope and complexity. Efforts amongst IEQ researchers are moving to address these issues. Cao et al. (2012) state that "Researchers have realised that people's discomfort is usually not determined by a single factor but instead reflects the integration physiological and psychological influences caused by many factors". But Kim and de Dear (2012) argue powerfully that there is currently no consensus as to the relative importance of IEQ factors for overall satisfaction. It can be seen that at a general level there remains a big gap between these putative elements and effectively understanding the holistic effects of environments on their occupants.

So, although it can be anticipated that the built characteristics of classrooms will have an impact on pupils' academic performance, it is actually rather tricky to disentangle all the factors involved and gain an understanding of exactly which characteristics are important, individually and in relation to each other. Thus, the Education Endowment Foundation (2014), in its well respected review of factors influencing pupils' learning noted how limited was the research in this area and concluded that: "changes to the physical environment of schools are unlikely to have a direct effect on learning beyond the extremes".

The HEAD Project has been working to bridge this gulf between a fairly high level of confidence in the literature about individual elements of the situation, and a lack of convincing evidence concerning their combined effect in practice. It can be seen that primary schools are an ideal focus to seek to address this knotty problem. The pupils spend most of their time in one space, their classroom, over a year and there are performance measures available, in this case their academic progress over that year (only one aspect of education, but an important one). If the physical characteristics of spaces do impact on people's performance, this is an ideal place to explore the connection. It is a very important focus too, as any results can benefit the educational opportunities of our young children.

- Bakó-Biró, Z., D. J. Clements-Croome, N. Kochhar, et al. (2012). "Ventilation rates in schools and pupils' performance." Building and Environment 48(0): 215-223.
- Cao B, Ouyang Q, Zhu Y, et al. (2012). "Development of a multivariate regression model for overall satisfaction in public buildings based on field studies in Beijing and Shanghai." Building and Environment 47: 394-399.
- Education Endowment Foundation (2014). Toolkit. Retrieved 18/11/14, 2014, from http://educationendowmentfoundation.org.uk/toolkit/.

Novel approach taken

To address this intractable problem the HEAD researchers attacked the complexity in two ways. First the "holistic" aspect of the practical experience of a space was taken fully on board. Second, a multilevel statistical modelling approach was used to isolate effects at the classroom level.

Holistic scope

Focusing on the first aspect, the challenge was how to take an holistic view without being overwhelmed by the amount and complexity of data. For this a strong conceptual framework was needed. The stance was taken that everything impacting on the senses of a person should be included and structured in the way the brain deals with this multi-sensory information (Rolls E T 2007). So, rather than build up from the easily measurable dimensions of heat, light, sound and air quality, we have developed a novel organising model. This reflects three dimensions, ie: that we seek certain natural features as being healthy, such as daylight; that we also react well to being able to adapt our surroundings to suit our individual preferences; and, lastly, that the level of stimulation provided for a space needs to be appropriate for the activity taking place. Thus the model behind the HEAD Study is unusually broad, but it is has a clear rationale and is structured in the following three parts (Barrett P and Barrett L 2010).

- Stimulation (appropriate level of): eg, complexity and colour;

- Individualisation: eg, ownership, flexibility and connection;

- Naturalness: eg, light, sound, temperature, air quality and links to nature.

Personal Environment
The opportunity of individualisation

Natural Environment
The role of naturalness

Task Environment
Appropriate levels of stimulation
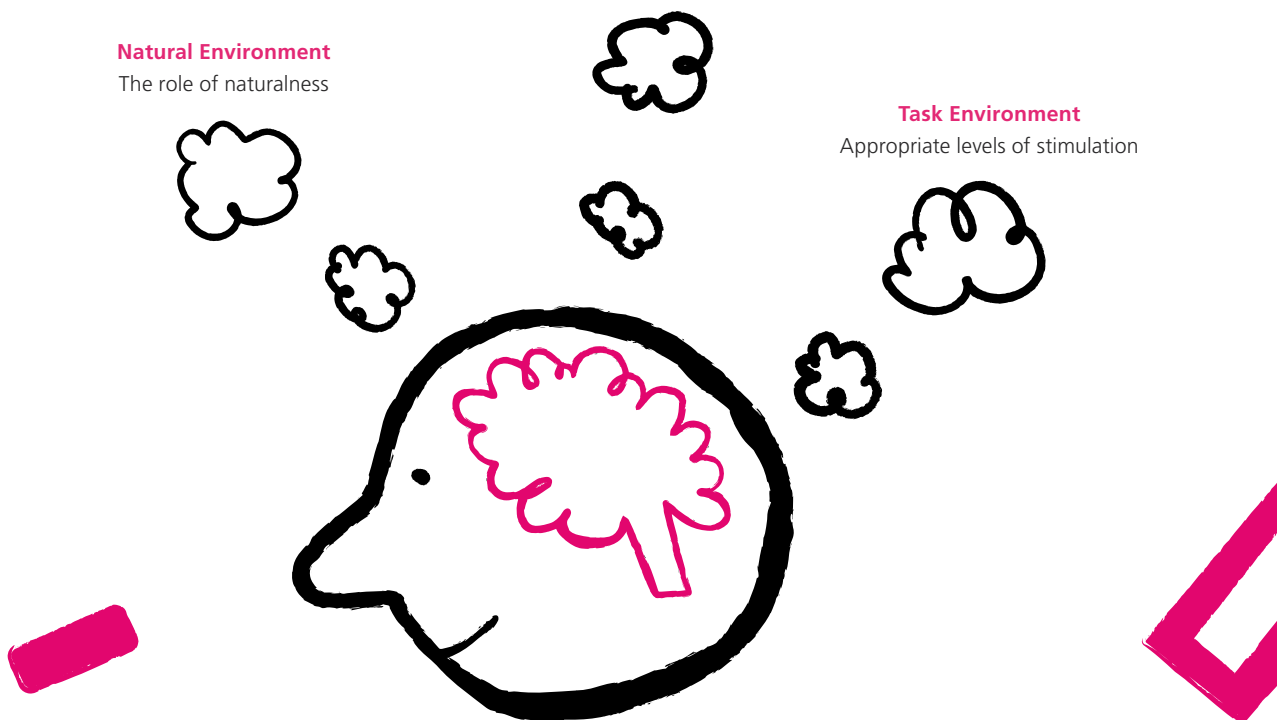
Organising Conceptual Model (SIN)

This approach places the individual at the centre of the analysis. Applied to primary schools it leads to a research design that has the pupils at the centre as shown in the figure. Thus, the pupils are sandwiched between non-built environment factors to the left, such as the effect of teachers, and, to the right, the built / physical features of the school environment. These latter draw on the full wealth of possible aspects, but structured into xis then a vertical flow in the figure, from the pupil's starting position academically, plus their individual characteristics; via their year spent in the classroom; to their achievements, measured in terms of their academic improvement, but possibly in terms of other aspects too, such as behavioural outcomes (although in practice these could not be captured).

School built environment (BE)

	Classroom	Rest of school
Naturalness	Daylighting / Fresh air / Noise	Bad WC / food smells / Views of nature
Individualisation	Low space density / inappropriate scale / Personalisation / Flexibility	Institutional feel / Lots of displays / Easy to navigate
Level of stimulation	Functional colours / Balance open / private / Clutter	Little outdoor space / Rich texture / Varied play facilities

Overview of the research design (with example factors)

Preparatory work had included a review of the relevant literature (Barrett P.S. and Zhang Y. 2009), surveys of pupils' and teachers' views and post-occupancy evaluations of a variety of schools (Zhang Y and Barrett PS 2010; Barrett PS, Zhang Y and Barrett LC 2011; Zhang Y and Barrett PS 2011). From this basis it was possible to take the concepts forward by creating a set of hypotheses suggesting how the various aspects of the physical school environment were likely to impact on pupils' progress in learning (see Appendix A). Then a range of primary schools had to be recruited and, in each, measures made of the various physical characteristics of the classrooms and data collected about the pupils in those classrooms, including their academic progress over the year. In selecting the schools the driving principle was to maximise the variation in the sample to optimise the opportunity to uncover their impacts. The scale and nature of the sample is set out in the next section.

References

- Nye B, Konstantopoulos S and Hedges L (2004) "How large are teacher effects?" Educational Evaluation and Policy Analysis,, 26 (3): 237-257.
- Barrett P and Barrett L (2010). "The Potential of Positive Places: Senses, Brain and Spaces." Intelligent Buildings International 2: 218-228.
- Barrett P.S. and Zhang Y. (2009). Optimal Learning Spaces: Design Implications for Primary Schools, SCRI Report, University of Salford.

Isolating classroom level effects
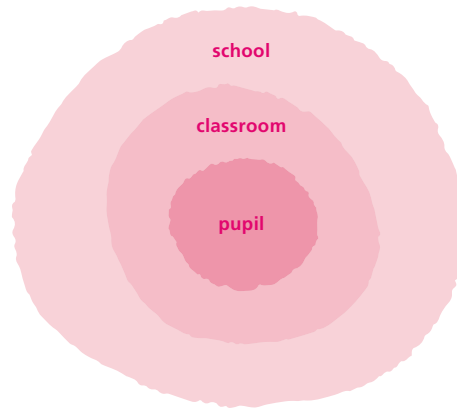
Multiple level modelling for nested situation: school classroom pupil

After the school visits and data collection the second major challenge was to distinguish between influences linked to the pupils and those operating at the classroom level. The data in this study is inherently nested, as groups of individual pupils occupy given classrooms and groups of classrooms make up given schools. This opens up the possibility of employing multilevel statistical modelling (MLM), which allows data to be clustered in groups. This then enables the impacts on learning that follow each individual pupil to be distinguished from those that vary along with groups of circa 30 pupils, ie whole classes in particular classrooms.

The structure of the MLM employed for this study was a two level model where pupils are nested within classrooms. A three level model, with classrooms nested within schools, was also tested, but as explained later, the school level of analysis did not prove helpful.

As well as helping to explain factors that have been measured at each level, MLM analysis also allows unexplained variance to be partitioned at each of the model levels. This is relevant at the pupil level, where some of the performance variation is owing to issues, such as parental influences, which cannot be assessed via the information collected in the study, however, the variability attached to the individual pupils can at least be separated out. At the classroom level it was possible to measure many physical factors and explain the variation in learning associated with these. However, it was not possible to factor in explicit measures of teacher performance. We did start out with this intention, but in practice were unable to obtain the relevant assessments of teachers from schools owing to understandable concerns about the sensitivity of the data. Thus, it is assumed that this

important element is left in the unexplained variance at the classroom level. Based on Nye et al.'s (2004) meta-analysis, the magnitude of the teacher effect explains somewhere between 7 - 21% of the variance in pupils' achievement gains and could readily be accommodated in this part of the model. There remained the possible issue of whether the findings about the impacts of physical factors were confounded in some way by the unmeasured teacher effects. A statistical test was designed for this and revealed no evidence of a confounding teacher effect on the physical factors measured. See Appendix B for more details of this test.

The aim of the study was to identify if there is actually any evidence for the hypothesised influences of the physical design of classrooms on learning progress. Bringing together the holistic data collected within the MLM allowed this aim to be addressed. The next section gives some details of the sample of schools studied and the section after that summarises the results, which were not always as expected. Appendix C provides more details of the MLM process.

References

- Barrett PS, Zhang Y and Barrett LC (2011). "A Child's Eye View of Primary School Built Environments." Intelligent Buildings International 3: 1-17.
- Rolls E T (2007). Emotion Explained. Oxford, Oxford University Press.
- Zhang Y and Barrett PS (2010). "Findings from a Post-occupancy Evaluation in the UK Primary Schools Sector." Facilities 28(13/14): 641-656.
- Zhang Y and Barrett PS (2012). "Teacher's View on the Design of Their Primary Schools." Intelligent Buildings International, 4:2, 89-110.

Study sample

**Geographical /
National Context**

To enable the effects on learning of different aspects of school design to be assessed, the main principle behind the selection of the schools to be studied was to achieve as much variety in the sample as possible, whilst still focusing on mainstream schools where there is some consistency in the broad context.

This study focused on the learning progress of English primary school pupils over a given year. All Local Authorities (LA) schools are obliged to follow a centralized National Curriculum (NC). In mainstream schools, there is a "mixed teaching methods" approach, utilising different learning zones to varying degrees, to support combinations of didactic, independent and group learning. This study collected data from 27 schools, in three local authority areas: Blackpool, Hampshire and the London Borough of Ealing. The areas were chosen for their diversity in geographical location and socio-economic context.

BLACKPOOL

LONDON BOROUGH
OF EALING

HAMPSHIRE

Schools

In English primary schools pupils spend the majority of their time in one classroom, making this group the ideal focus for the study. The school buildings within the study were chosen to have a wide spectrum of different architectures, built at different times and of different sizes. The schools ranged from small, mixed year group, village schools, with only 103 pupils, to multi-year intake schools, with 819 pupils. The ages of the buildings ranged from Victorian (circa 1880's), to post 2000 builds.

1900's

1920's

1950's

1970's

2000's

Admissions total classes

Total floor area (m²)

Total pupils

□ Urban
○ Between
△ Rural

Site area (m²)

Study sample

Classrooms

In the 27 schools selected, 153 classrooms were studied. Where possible, in each school a classroom for each of Years 1-6 was selected. In bigger schools this presented a choice and so additional diversity was injected by choosing classrooms with different orientations, or where the buildings dated from various periods, from different parts of the school.

The data collection consisted of two surveys: a detailed survey for each selected classroom and a whole school survey, taking measures of shared spaces. In the classroom part of the survey:

- Architectural measures were taken, such as: room dimensions and learning zone layouts, plus an extensive photographic record.

- A range of further factors assessed included: how much control there was of the classroom environment via heating controls and layout flexibility; and the colour and visual complexity of the space.

- In addition five spot meter readings (temperature, light, humidity, CO2 levels, acoustics) were taken in each of the rooms to assess the environmental conditions at the time of the visit, in order to provide possible prompts regarding problem areas.

- Lastly, a questionnaire-based interview with each teacher was carried out, investigating their experience of their classroom, over the whole of the year.

Taken together this provided a rich record of the classrooms and the shared spaces. Based on this data ratings were made of the various components of the SIN Model.
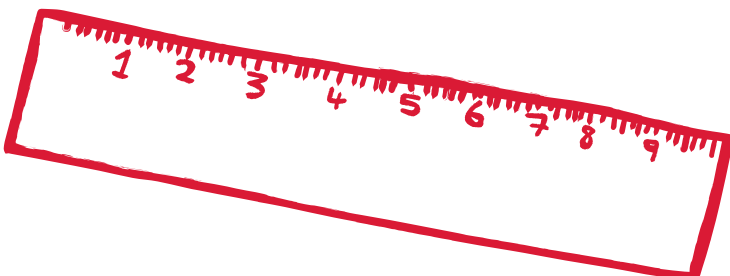
Pupils

Anonymised data was gathered for the pupils occupying each of the classrooms studied. If any pupil record was incomplete then it had to be excluded. Full data was obtained for 3,766 pupils aged 5 to 11 years, in classes from year 1 to year 6.

As well as fixing the classroom they had occupied, background information was collected for each pupil, such as their age, gender, and if they qualified for free school meals, had special educational needs or had English as an additional language. The key data for each pupil in this study were their starting and finishing teacher assessed grades in Reading, Writing and Mathematics, from which their progress in each subject could be calculated. The main performance measure was the pupils' academic progress over the year, taken as the aggregate of the progress made in each of the three subjects. This broad measure would seem a logical approach, as all three subjects are studied together in the same classroom.

Girls
1871 – 50%

Boys
1896 – 50%

Year 6
605
16%

Year 1
447
12%

Year 2
606 – 16%

Year 5
708 – 19%

Year 3
744 – 20%

Year 4
656 – 17%
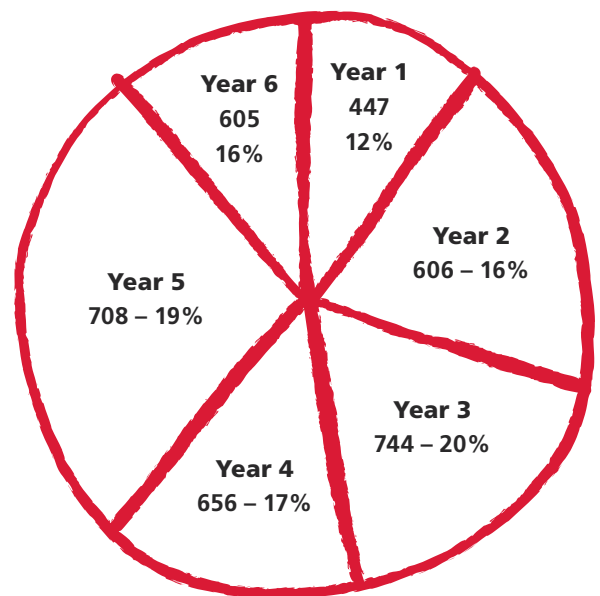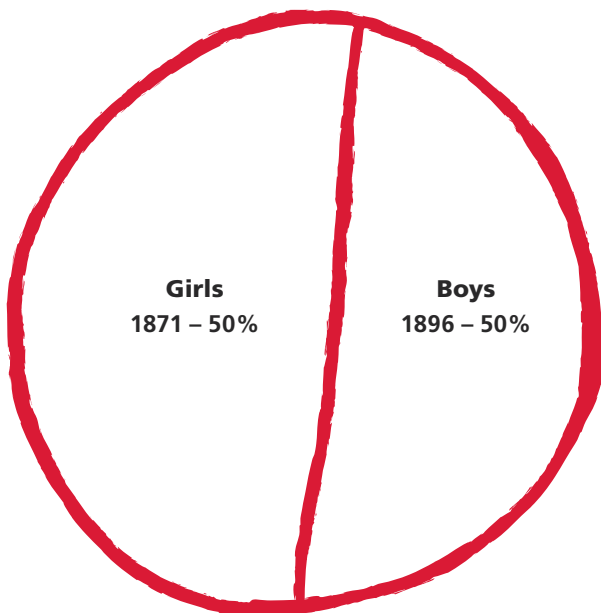
Diversity in sample – highlighting gender and year of study

Main findings

The single most important finding reported here, is that there is clear evidence that the physical characteristics of primary schools do impact on pupils' learning progress in reading, writing and mathematics. This impact is quite large, scaling at explaining 16% of the variation in the overall progress over a year of the 3766 pupils included in the study. By fixing all factors to their mean scores, except the physical environment factors, the impact of moving an "average" child from the least effective to the most effective classroom has been modelled at around 1.3 sub-levels, a big impact when pupils typically make 2 sub-levels progress a year. As far as we are aware, this is the first time that clear evidence of the effect on users of the overall design of the physical learning space has been isolated in real life situations.

This conclusion was reached after the impacts on learning of the Stimulation, Individualisation and Naturalness (SIN) characteristics had been assessed using a multi-level modelling process (MLM). Within these three principles, ten design parameters were first each individually tested (using bivariate analysis) for their impact on learning. These each had some impact, as predicted by the literature, but when they were combined in the MLM their significance and relative importance changed owing to interactive effects and the factoring out of the effects of pupil characteristics (see Appendix C).

It can be seen that the overall impact of 16% is driven by a wide range of factors, with no single one being dominant. This supports the notion that the impact of the physical space occupied is indeed an holistic experience in which a full range of factors are in play, together. Looking at seven significant design parameters it is interesting that those that are normally studied fall within the Naturalness category and are indeed important, but only account for around half the effect found. The other two categories, "Individualisation" and Stimulation", taken together,

are as important to users' experience of the spaces they occupy. This expansion to include these novel design principles represents a shift from a relatively passive focus on "comfort" to a fuller consideration of the active response of people to their built surroundings. Interestingly, the appropriate level of stimulation for learning turns out to be curvilinear – neither chaotic, nor boring, but somewhere in the middle. That is, it is easy to over-stimulate pupils with vibrant colours and overly busy displays, but a white box is not the answer either.
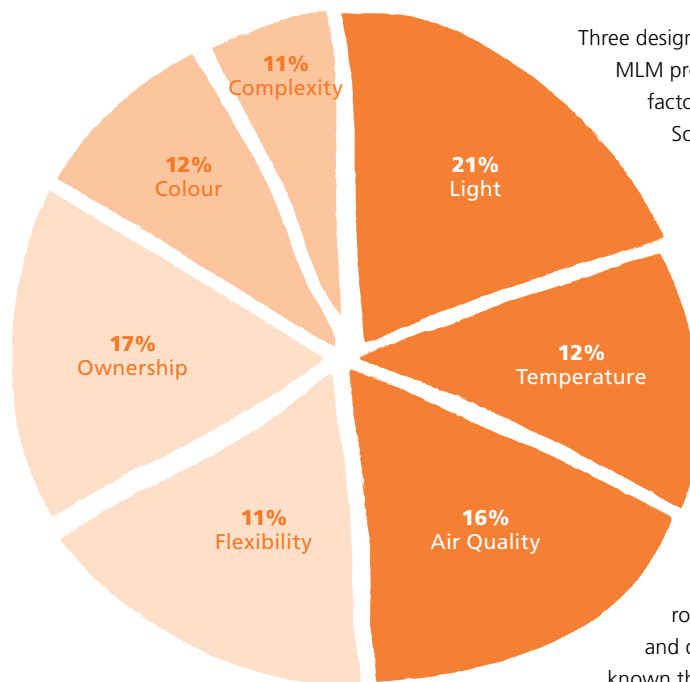
Three design parameters were competed out in the MLM process by the above, more influential, factors. The aspects that dropped away were Sound, Links to Nature and Connection. In some sub-analyses these do appear to be relatively more important for some sub-categories of pupils and some specific subjects. So, in the next section they are included, but clearly labelled as "secondary factors".

A surprising finding is that physical design factors at the school level of analysis did not come through as being of sufficient importance to appear amongst the main factors at all. These covered the size of the school, the provision of shared specialist rooms, routes through the school, the scale and quality of external spaces, etc. It is well known that pupil factors are important, but the HEAD study unusually assessed individual classrooms as well as whole-school factors. Once the pupil effects have been addressed, it would seem that in primary schools, when addressing formal learning, the overwhelming focus should be at the classroom level, as there is very little variation in learning associated with the school level of analysis. The partitioning of the variation within the MLM shows 54% of the variability is at the pupil level, 43% is at the classroom level and only 3% is at the school level. This seems to reflect the reality that primary school pupils relate strongly to their classroom, with their teacher, where they spend the great majority of their time.

The factors found to be significantly influential via the MLM were, in order of influence:

- ◉ Naturalness: light, temperature and air quality – accounting for half the learning impact
- ◉ Individualisation: ownership and flexibility – accounting for about a quarter
- ◉ Stimulation (appropriate level of): complexity and colour – again about a quarter.

Of course the design of the school as a whole has to be attended to, but the message is that first and foremost the individual classrooms must each be well designed. This may sound obvious, but our findings show that it is very common for classrooms within a given school to vary considerably in their modelled impact on learning. This could be for many reasons, for example, because of the different orientations of various rooms, or ages of parts of the building, or the ways in which the spaces are being used, etc. As the figure illustrates (showing ten schools drawn from one of the local authority areas studied) the variations in impacts are dramatic. Each column of points represents an individual school and the points themselves classrooms within the school.

Variation in the modelled impact of classrooms
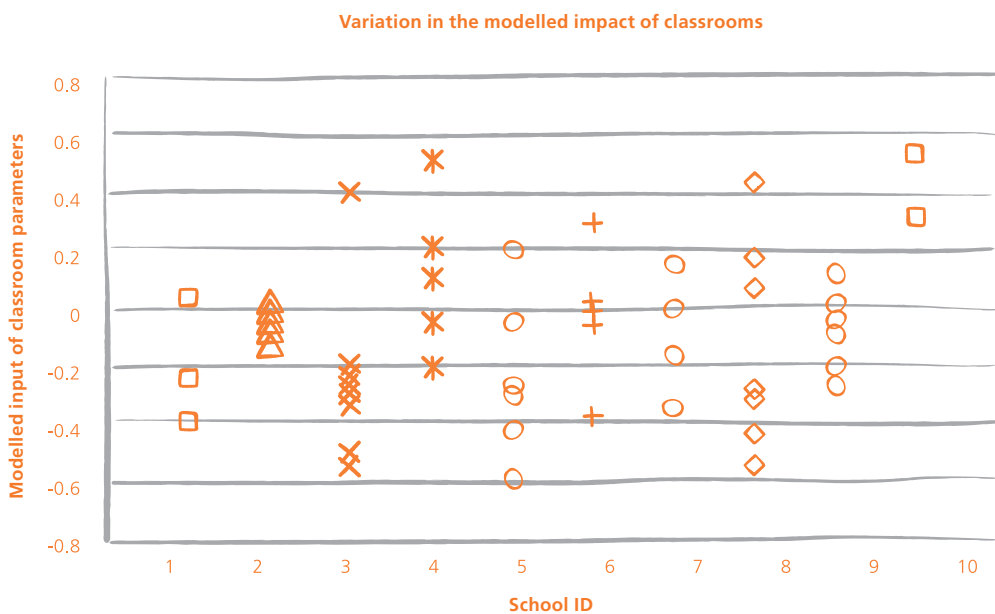
A very positive finding is that users (teachers) can readily action many of the factors. When the pilot results of the HEAD study were aired in 2013 the Department for Education said, "There is no convincing evidence that spending enormous sums of money on school buildings leads to increased attainment". However, these final results, based on a five-fold increase in the sample, show that small changes costing very little, or nothing, can make a real difference; for example, changing the layout of the room, the choices of display, or colour of the walls.
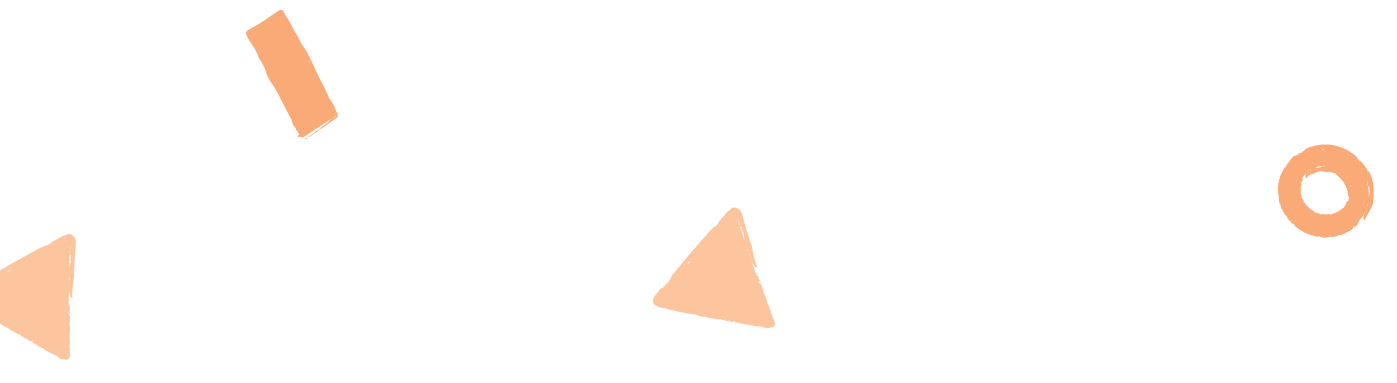
Detailed results and practical check points

This section provides more details about the findings for the specific aspects identified as being particularly important for achieving effective learning environments. For each factor there is a two-page spread with the findings set out on the left-hand side and, on the right-hand side, checkpoints for designers and for teachers providing practical suggestions to be taken into account.
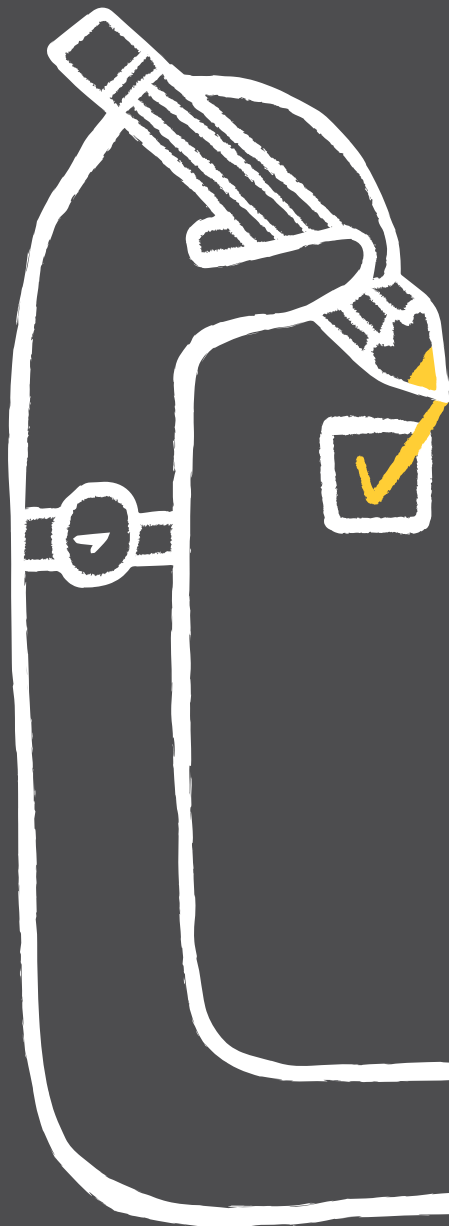
This material is strictly based on, and illustrated from, our study sample. Thus it truly represents the factors that lead to the 16% influence found. It does, however, mean that the issues shown could in some ways be thought to be everyday. The important thing to note is that, although this is undoubtedly often the case, these seemingly mundane aspects are the factors that we have now evidenced really do impact on learning. Some will seem obvious, but it is clear from our fieldwork that they are not so obvious that they are consistently addressed!

It will be necessary for any designer or teacher to take the findings and adapt them for the situation they are confronted with. There will, no doubt, be many other competing factors to take into account, but it is hoped that the issues highlighted here will now not be inadvertently crowded out. In addition there will be ways of addressing the principles behind the optimal factors that are not found in our sample, but which creative designers and teachers will doubtless develop.

Naturalness

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. Deep classrooms can create a disparity in light levels between the back of the room and the area near the window.

Although natural daylighting should always be the main source of lighting in schools, it will need to be supplemented by electric light when daylight fades (BB87). Tanner (2009) carried out a survey of 71 US elementary schools, examining the impact of natural light and sources of artificial light in classrooms. The results provide evidence that good lighting significantly influences reading vocabulary and Science test scores.

Of all the design parameters considered, lighting has the strongest individual impact. The main practical considerations are as follows:

○ Glazing orientation and glazing area: High levels of natural light via large windows to the classroom are optimum, moderated by a need to avoid glare from direct sunlight. Glare is now a greater issue because of the widespread use of interactive whiteboards and computer projection in UK classrooms.

○ Artificial lighting: Both a good quality and quantity of electrical lighting are always needed to supplement classroom illumination at times and in areas where natural light is inevitably not sufficient.

○ Glare control: Blinds (sufficiently opaque) that function effectively to control light levels are best. They should be easy to use. Some types of blinds can cause excessive noise or air flow issues (see air quality findings); External shading to sunlit windows can also provide protection.

Illustrations of window orientation and size combinations

Poor
Very large glazing ratio, south-east facing.

Good
Small glazing ratio, south facing.

Poor
Small glazing ratio, north facing.

Good
Large glazing ratio, east facing.
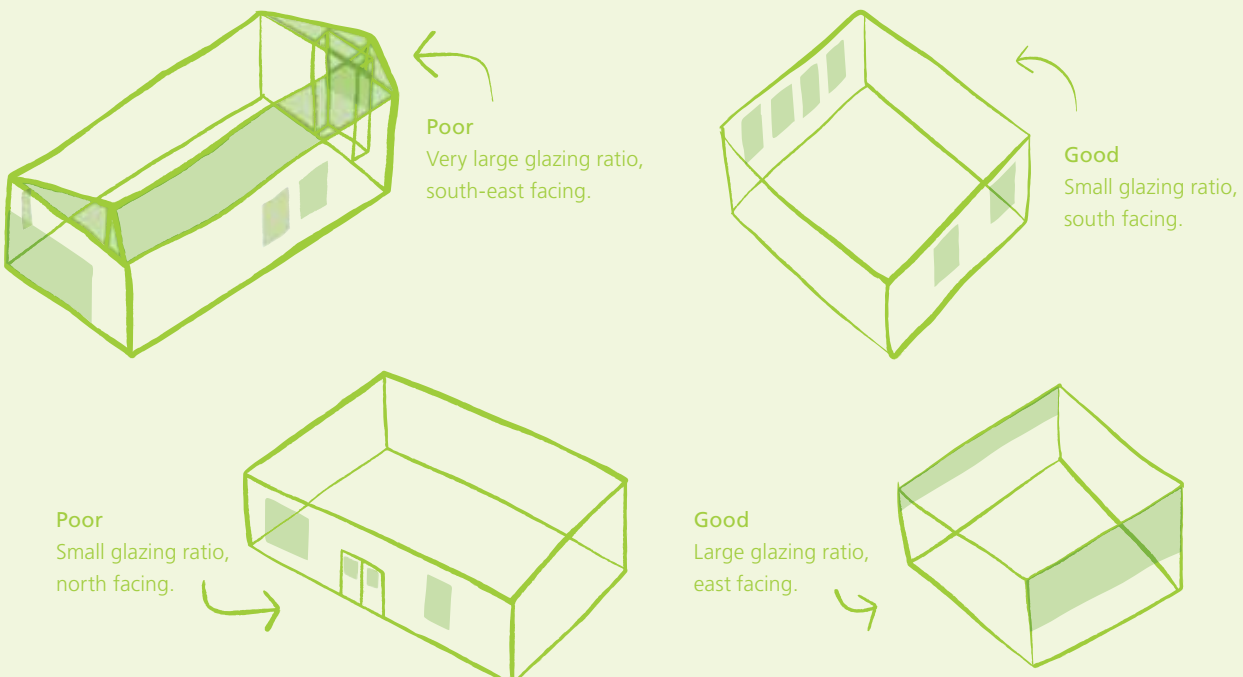
Checkpoints for designers

Advice here is given for UK latitudes but similar considerations will be needed for other locations.

○ Large glazing is welcomed when it is towards the North, which has the most uniform daylight throughout the day and year and seldom experiences problems with glare discomfort.

○ Classrooms facing the east and west can receive abundant daylight and have a low risk of glare during the normal times of occupation.

○ Expansive glazing should be avoided when it is orientated South, towards the sun's path for most of year.

○ When large glazing is applied towards the South, external shading should be provided to control the degree of sunlight penetration.

○ Also, abundant, high quality electrical lighting is essential to provide a reasonable visual environment.

Checkpoints for teachers

○ Minimising or avoiding displays on the windows, especially those towards the outside. Similarly not placing large items of furniture against windows. Keeping the glazing clear can maximise environmental benefits from natural light.

○ Active use of the internal blinds (shading coverings) to address any glare problems. Keeping access to the blind controls clear. When there is a low risk of glare, keeping the blinds open, instead of simply switching the light on can maximise environmental benefits as well as saving energy.

○ The use of a high power projector, carefully sited, can minimise the need to use blinds.

○ Shrubs or planters placed outside south-facing windows can reduce problems of too much incoming light.

This classroom has two windows towards different orientations. One of the windows is heavily occluded with high-height furniture (pictured), which reduces both light levels and cross ventilation.

References

● DFES (2003) Building Bulletin 87 (BB87), 2nd Edition Version 1 (May 2003) Guidelines for Environmental Design in Schools,

● Tanner, C. (2009) Effects of school design on student outcomes, Journal of Educational Administration, Vol. 47 No. 3, 2009. pp. 381-399.

Naturalness

Air quality

Background

Air quality has become increasingly problematic owing to a variety of factors, such as: energy efficiency constraints and universal use of carpets (Burberry 1997). Daisey et al. (2003) reviewed the literature on indoor air quality, ventilation, and building-related health problems in schools and identified commonly reported building-related health symptoms. 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 volume each owing to high occupancy density (Crawford and Gary 1998). A recent study made an intervention to improve ventilation rates in 16 classrooms. The results of computerized tasks performed by more than 200 pupils showed significantly faster and more accurate responses for Choice Reaction, Colour Word Vigilance, Picture Memory and Word Recognition at the higher ventilation rates (Bakó-Biró et al. (2012). Evidence also indicated that poor air quality is rather a common problem in schools.

Our Findings

Poor air quality in the classrooms studied was often noted during our visits. However, good features are as follows:

○ User controlled ventilation: Windows with large opening sizes, ideally provided via multiple openings, allow users to ventilate the room effectively under different circumstances. Top openings that are high in the room, but easy to use, allow the hottest and stalest air to escape more efficiently. Roller blinds that block air flow through the top opening windows can cause poor air quality due to low ventilation rates.

○ Room volume: In large rooms excessive levels of carbon dioxide and poor air quality are less likely to occur due to dilution within the large volume of the room.

○ Mechanical ventilation: In situations where natural ventilation is problematic, air quality can be improved with mechanical ventilation

Illustration of the impact of room volume on air quality

For the rooms from our sample with the biggest and smallest volumes, for a one hour lesson, with 30 "resting" pupils and no ventilation, the air quality becomes poor (+1000 ppm of CO_2) after:

○ 26 minutes with the smallest room (Volume = 78 m3)

○ 55 minutes, even with the biggest room (Volume = 300 m3)

○ The figure is 30 minutes for the "average" room (Volume = 181m3 (Respiratory frequency and tidal volume from Singh and Sivakamasundari, 1966)
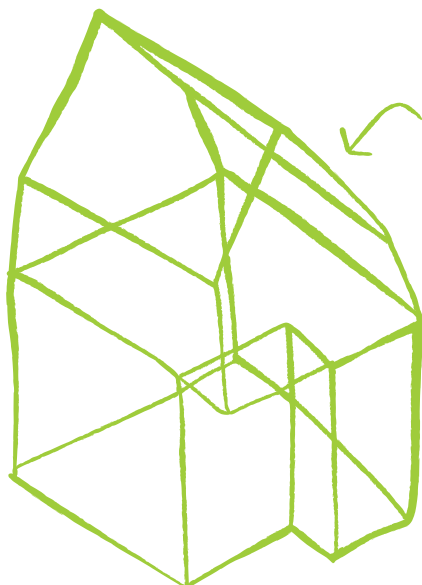
Biggest
$300m^3$
Room volume ($300.0m^3$)
High ceiling (avg. 5.2m)
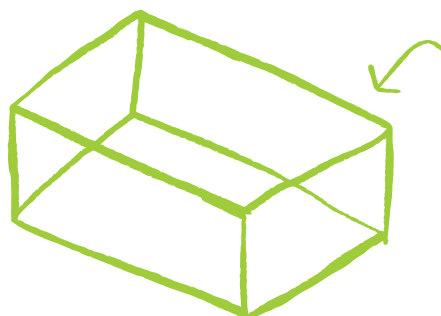
Smallest
$77.5m^3$
Room volume ($77.5m^3$)
Low ceiling height (avg. 2.3m)

Checkpoints for designers

O Big window opening sizes, at different levels (and orientations), can increase the air exchange rate and also provide ventilation options for varying conditions. The controls should be easy to access and use.

O Where possible, increasing the ceiling height can improve the air quality of the classroom as it can absorb more stale air in the short term, but effective ventilation is still needed.

O Mechanical ventilation to introduce fresh air may sometimes become necessary when window openings are not available due to noise or security reasons. In this case, it is important that users should be educated to ensure their intended use. Air cooling (but not renewal) can mask poor air quality and create cold spots.

Checkpoints for teachers

O Opportunities to improve air quality should be grasped. In a typical classroom with thirty pupils it will normally be necessary to open a window within the duration of a lesson. If not practical, opening the windows between the classes is strongly suggested.

O Avoiding obstructions to access the window/s can make their operation easier.

O CO2 is not considered a contaminant or pollutant, however, it is widely recognized as an indicator of ventilation rates. A CO2 meter installed in the classroom can give teachers (and maybe pupils) a clearer view to act / correct their environment.

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

trickle ventilators for cold weather, high winds and when other windows are closed for security;

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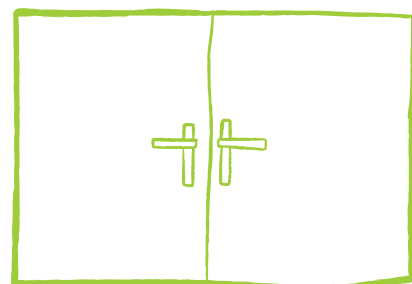
small windows at bench height for all-round ventilation – may have to be closed in high winds to prevent papers flying.

References

● Bakó-Biró, Zs., Clements-Croome, D., Kochhar, N., Awbi, H., Williams, M. (2012) Ventilation rates in schools and pupils' performance, Building and Environment 48 (2012) 215-223
● Burberry, P. (1997) Environment and services. 8th ed. ed. Mitchell's building series. 1997, Harlow: Longman. vi, 384 p.
● Crawford, E., Gary N.(1998) Going Straight to the Source American School & University, v70 n6 p26,28 Feb, 1998
● Daisey, J., Angell, W., Apte, M. (2003) Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information, Indoor Air 2003; 13: 53–64
● Singh, H., Sivakamasundari S. (1966) Respiratory minute volume and tidal volume in normal boys, Indian Journal of Pediatrics, Dec 1966, Vol. 33 Issue 227, 391-394

Naturalness

Temperature

Background

Researchers have been studying the temperature range associated with better learning for several decades. Zeiler and Boxem (2009) carried out a thorough review to clarify the effects of thermal quality in schools on the learning performance of the students. Mendell and Heath (2005) critically reviewed evidence for direct associations between the indoor environmental quality and performance or attendance. As temperature and humidity increase, students report greater discomfort, and their achievement and task-performance deteriorate as attention spans decrease. Thus, cooler is best in terms of pupils' learning efficiency (Wargocki and Wyon, 2007). A UK survey run by a teachers' union noted, from teacher submitted data, that in almost 5% of classrooms, on-the-spot temperatures of over 30 C were found (NASUWT, 2012).

Our Findings

Teacher / Classroom control of temperature was found to be the most important factor in the Temperature category.

○ Central heating control: Better temperature control was found when rooms had radiators with thermostatic controls. In contrast under-floor heating seemed to be associated with poor heating control in individual classrooms.

○ Orientation and shading control: The temperature was better controlled where the orientation ensured there was no direct sun heat into the room, however, direct sun heat can be eliminated using external shading devices. Sun-facing skylights with no external shading can add unwanted sun heat into the room.

Illustrations of orientation and shading provision

Poor: no external or internal shading control (left)

Good: abundant sun heat but with external shading devices, e.g. canopy (top), overhangs (bottom)

Checkpoints for designers

- Radiators with thermostats in each room give users better opportunities to dynamically maintain the temperature at a comfortable level.

- Underfloor heating systems have merits, but the controls and response lags need very careful attention.

- Classrooms facing north avoid the sun's radiant heat, while those towards the east and west receive little sun heat for most UK classrooms. These all have a lower risk of overheating than classrooms facing towards the south.

- For those classrooms facing towards the sun's path most of the time / year, an external shading device is needed.

Overhang	Outriggers	Louvres

★ ★ ★ ★	★ ★ ★ ★	★ ★ ★
View good	View good	View restricted

Here are some examples of types of exterior shading device specifically for south facing windows. If they can be moveable they can respond to the unpredictable daily variations given the dynamic nature of the UK weather.

Checkpoints for teachers

- If local control is possible (by the thermostat) the temperature of the classroom should be kept cool but comfortable for optimum learning conditions.

- If sun heat gain is a problem and there is no external shading, then the combined use of blinds plus ventilation can mitigate the problem.

- Shrubs or planters placed outside south-facing windows can provide shading to reduce sun heat gain.

References

- Mendell, M., and Heath, G. (2005) Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature, Indoor Air 2005; 15: 27–52
- Wargocki, P., Wyon D.(2007) The Effects of Moderately Raised Classroom Temperatures and Classroom Ventilation Rate on the Performance of Schoolwork by Children (RP-1257), HVAC&R Research,2007, 13:2, 193-220
- NASUWT (2012) Campaign on excessive temperatures in the classroom. Available at: http://www.nasuwt.org.uk/consum/ groups/public/@press/documents/nas_download/nasuwt_009168.pdf accessed 18/11/14
- Zeiler, W. and Boxem, G. (2009) Effects of thermal activated building systems in schools on thermal comfort in winter, Building and Environment 44 (2009) 2308–2317

Naturalness

Sound – a secondary factor

Background

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 auditoryperception 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 background noise not only improves communication but also promotes working and learning efficiency.

Crandell and Smaldino (2000) and Picard and Bradley (2001) summarized the trends from many studies and indicated that the acoustic environment of a classroom is a critical factor in the academic and psychosocial achievement of children.

Our Findings

Although Sound does seem to have some effect on learning, in our multilevel modelling (MLM) it was competed out in importance by other factors. This could be because noise disturbance is very tangible, so tends to be sorted out and so is less evident in practice. It could be classrooms are generally only moderate in size and teachers can make themselves heard. Either way, in this context, of limited evidence, the following would however seem to be worth taking into account if possible. This is all the more so in the case of pupils with Special Educational Needs, as Sound does remain in the MLM of just this sub-sample.

- External noise: Rooms that are situated away from busy areas such as the playground or reception areas have less external noise. Traffic noise being heard in the classroom can also be a problem where there is no acoustic buffer such as distance plus trees and shrubs.

- Internal Noise: Unwanted noise internal to the classroom can be reduced if chairs have rubber feet. Internal acoustics are also improved where the classroom has large carpeted areas.

- Room Shape: It is easier for teachers to be heard by pupils when the seating arrangement allows pupils to be closer to the teacher. A room where the length to width ratio is higher allows this type of seating arrangement.

Checkpoints for designers

○ The school should be sited away from busy roads. At the same time, it ideally needs to keep a reasonable distance from adjacent users in the neighbourhood.

○ Planning measures can integrate site features, such as slopes or embankments, as barriers to considerably diminish the intrusion of noise. If these are covered with plants, then the noise can be further reduced.

○ Sensitive spaces, such as classrooms can be orientated away from external noise sources and carefully separated from the intruding noise from other uses. The toilets, storerooms and corridor can act as a buffer zone.

○ There is more flexibility for teachers to use the room layout for general presentations when the classroom is rectangular on plan rather than a square.

Checkpoints for teachers

○ The effect of adding sound-absorbing treatment to rooms is significant. Porous materials are a good acoustic absorber, so a sound-absorbent surface (soft texture) can be used in order to change the sound characteristic of the space.

○ Rubber feet on movable furniture, e.g. chairs and desks, can provide floor protection and buffer the noise that is generated, if kept in good condition.

○ Small carpeted/rug areas can make a positive difference to noise attenuation in busy areas.

The flooring has been mentioned above, but the ceiling can also be important in improving the acoustic quality of the classroom. It is the biggest surface in the room and it stays flat and relatively untouched.

The installation of a false ceiling with acoustic tiles can often be effective (Hegarty et al. 1998). In the case shown, curtains have been used to get better acoustic results by dampening the echoes and avoiding reverberation.

References

● Crandell, C., Smslfino, J. (2000) Classroom Acoustics for Children With Normal Hearing and With Hearing Impairment, Language, Speech, and Hearing Services in Schools, Vol. 31, 362–370, October 2000

● Hegarty, M., Phelan, A., Kilbride, L. (1998) Classrooms for Distance Teaching and Learning: A Blueprint, Leuven University Press (Dec. 1998), 270 pages

● Picard, M., Bradley, J. (2001) Revisiting speech interference in classrooms, Audiology 2001, 40: 221- 244

Naturalness

Link to nature – a secondary factor

Background

Research suggests evidence of profound benefits of the experience of nature for children, due to their greater plasticity and vulnerability (Wells and Evans, 2003; White 2006). It is argued 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 possibilities, such as encouraging children's interest in problem solving; promoting social interaction; enhancing physical and cognitive development; encouraging imaginative play, and stimulating empathy.

Our Findings

Although some evidence of impacts specifically on learning was found, this did not survive the multilevel modelling (MLM) and was competed out by other, more important factors. That said, MLM sub-analyses indicated that Links to Nature may be more important for the creative process of Writing and for pupils in heavily urban environments. In the context of this limited evidence, the following would seem to be worth taking into account if possible:

○ Views of nature: Rooms from which pupils can view nature seem preferable. This includes natural elements such as grass, gardens, ponds, and trees. The window must have window sills at or below the pupils' eye level.

○ Access to nature: Classrooms with doors directly towards a play area outside were scored positively.

○ Natural elements in the classroom such as plants (surprisingly rare) and wooden furniture can also be important.

Illustrations of varying views out through the window

Poor: Parking spaces, few green and natural elements

Good: Interesting close and distant view

Poor: Small window area, high window height (1.4m), no distant view

Checkpoints for designers

○ One function of the window is maintenance of a visual link between the indoor and nature outdoors. Where possible, the view through the window should be plentiful, providing a wide-field vision of landscape.

○ The sills of windows onto a good view need to be at or below the children's eye level, or their view is purely theoretical!

○ When the classroom is on the ground floor, a door directly towards a external play area can give pupils easy access to the natural outside.

Checkpoints for teachers

○ Excessive displays on windows or items of furniture placed in front, will block the children's view through the window (and also reduce the natural light into the room).

○ Natural elements in the classroom such as plants, wooden chairs and /or desks allow pupils to experience natural elements.

Example of a view out through the window:

○ Large window provides a broad vision outside.

○ Plenty of green area can express the seasonal cycles.

○ The view is always available, even when the pupils are seated, as the sill height is low.

○ The door gives pupils easy access to the outside. But, the displays are starting to block the view.

References

● Wells, N., Evans, G. (2003) Nearby Nature: A Buffer of Life Stress among Rural Children, Environment and Behavior, Vol. 35 No. 3, May 2003 311-330

● White, R. (2006) Young Children's Relationship with Nature: Its Importance to Children's Development & the Earth's Future, Taproot, Fall/Winter 2006, Vol. 16, No. 2; The Coalition for Education in the Outdoors, Cortland, NY.

Individualisation
## Flexibility

Background

Classrooms play a most important role as they are the core learning spaces of a school. Classrooms can support individualisation by offering a variety of opportunities for different modes of learning. Longer term, they need to accommodate changes in pedagogical goals, educational programmes or instructional strategies. Building Bulletin 99 (2006) specified that the flexibility must be a key design requirement within school builds and Higgins et al. (2005) note that it is necessary for all classrooms to have some degree of flexibility.

Our Findings

○ Breakout space: Classrooms with clear breakout zones or breakout rooms attached were found to impact positively on learning. Breakout zones within corridors and separate from the classroom do not appear to be effective.

○ Storage: Good and accessible storage is important in classrooms but too many cupboards can take up useful learning space. Placing storage in corridor spaces is a good solution, eg cupboards, coat pegs, so long as it does not impede circulation.

○ Learning zones: Younger pupils, who spend a lot of their time engaged in play-based learning, benefit from a larger number of different learning zones. For older pupils who spend more time engaged in individual formal learning or group work fewer learning zones are needed.

○ Room shape and area: Rooms with varied floor plan shapes provide greater potential for creating different activity areas for younger pupils. For older pupils squarer and larger rooms work better in facilitating their learning opportunities.

○ Wall area: Large, accessible wall areas provide flexible opportunities for the display of information and of pupils' work.

Key Stage 2
Rating: Poor
Area 52m^2
Perimeter 46m

Teaching Wall

Key Stage 1
Rating: Good
Area 64m^2
Perimeter 40m

Teaching Wall
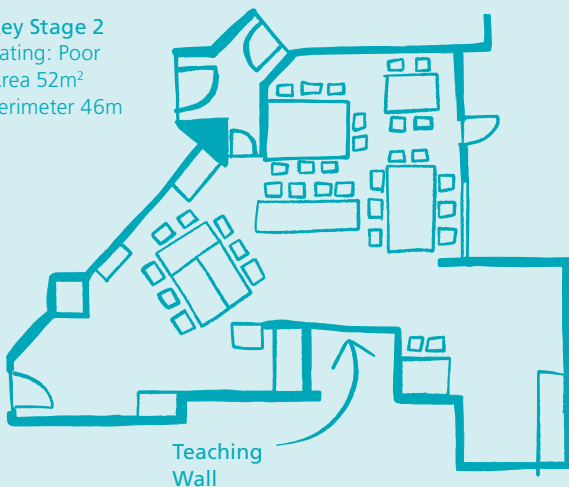
In complex shaped rooms, especially if it is smaller, it is harder to create the more formal learning arrangements often used for older children
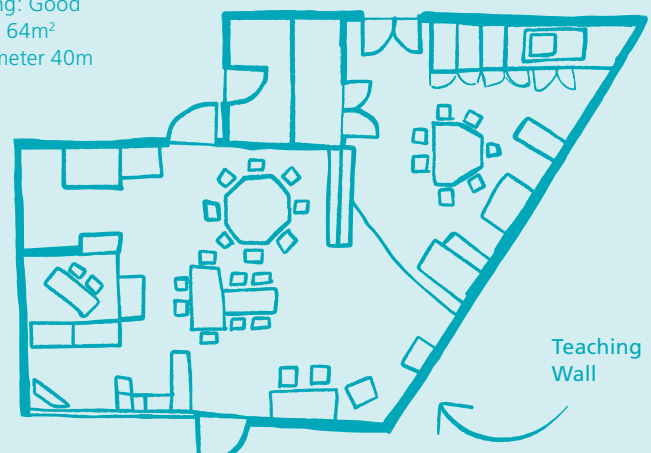
In complex shaped rooms, it is easier to create varied learning activity zones for younger grades to fit the typical pedagogical approach adopted.

Checkpoints for designers

O Breakout space/s with a clear boundary (enclosed), attached to the classroom is beneficial for one-to-one and small group support in a more private atmosphere.

O A widened corridor adjacent to the classroom can be used for for storage, e.g. cupboards, pupils' coat pegs, lockers etc., so releasing valuable classroom space .

O A more complex floor plan provides good potential for creating different activity areas for younger children (KS1).

O A larger area, with a simpler shape, is appropriate and more flexible for older children (KS2).

O A big wall area (excluding window and door areas) for display is desirable.

Checkpoints for teachers

O Well-defined learning zones are important for teachers to facilitate appropriate learning options.

O Younger pupils need many well-defined zones for varied learning activities at the same time, e.g. carpet area, reading corner, pc corner, role play, wet play, teacher station etc. Care should be paid to avoiding clashes with through routes.

O For older pupils, simpler space configurations (fewer zones) support more formal individual or group work, without cluttering the classroom unduly.

O Lower height furniture will make more wall area available for varied display options.
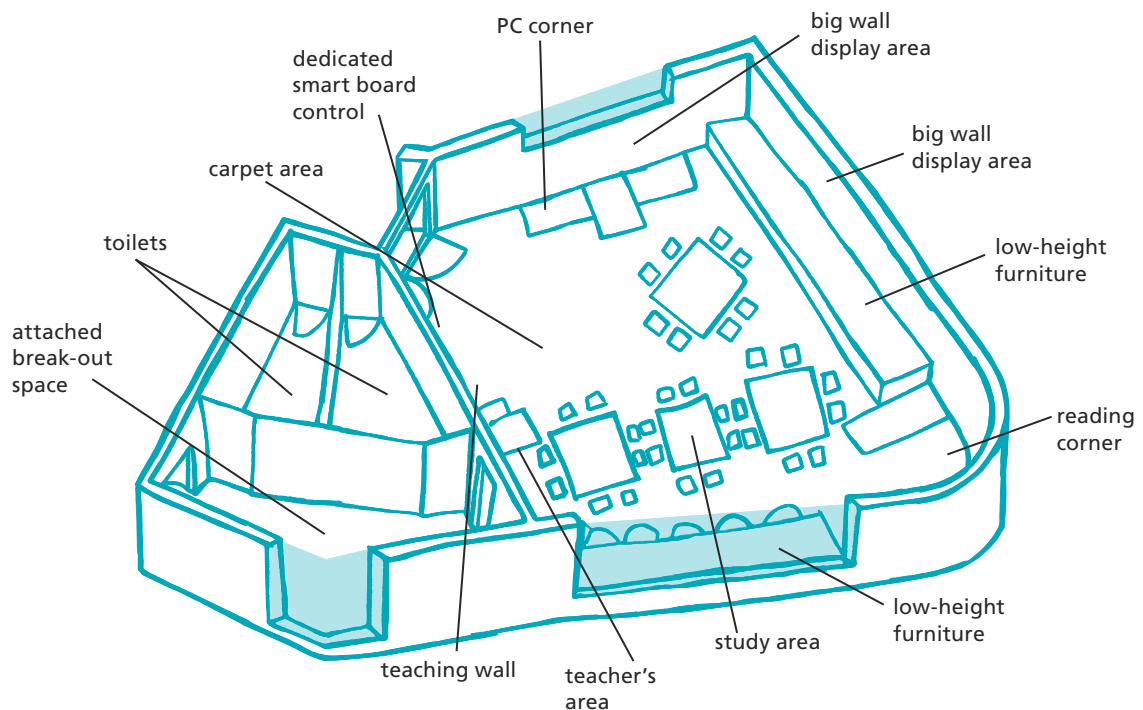
A classroom with several good features of Flexibility: defined learning zones, big wall area and an attached breakout space.

References

● DfES (2006) UK Department for Education and Skills, Briefing Framework for Primary School Projects, Building Bulletin 99, 2006, 67 pages

● Higgins, S., Hall E., Wall K., Woolner, P., and McCaughey, C. (2005) The Impact of School Environments: A literature review. Design Council. London.

Individualisation

Ownership

Background

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. It is argued that intimate and personalised spaces are better for absorbing, memorizing and recalling information (McMillan 1997). When children feel ownership of the classroom, it appears the stage is set for cultivating feelings of responsibility (DeVries and Zan 1994). Classrooms that feature the products of students' intellectual engagements, projects, displays, and construction are also found to promote greater participation and involvement in the learning process (Ulrich 2004).

Our Findings

A range of factors were found to be important in two categories: aspects that helped pupils identify with "their" classroom; and aspects that are child-sensitive.

- Room design: A Classroom with a distinctive room design, or particular characteristics making it instantly familiar.

- Room display: Pupils' work is displayed on the walls. Other elements such as shared display tables.

- Elements that are personalized by the pupils: such as coat pegs, lockers and / or named drawers.

- Furniture, fixtures and equipment (FF&E): Well-designed furniture that creates a learning space that is child centred.

- Chairs and desks: Desks and chairs that are comfortable, interesting and ergonomic to the pupils' ages and sizes.

Illustration of the nature of displays created

It may not be clearly visible, but this illustration gives the feel of a classroom that had lots of class-made art work on display in varied formats and sizes.

Checkpoints for designers

Classrooms should have distinctive design characteristics, ie not just a "box".
For example this could involve:

- shape (L shape; T shape)
- design (embedded shelf for display, play/display corners).
- elements specifically designed for children (low height windows, sinks).
- distinctive ceiling design.
- location (separate buildings)

Checkpoints for teachers

- A classroom that includes pupil-created work in displays is more likely to provide a sense of ownership.

- The classroom can be made readily recognisable from others by distinctive class-made displays / artwork of, for example, people, houses, animals, trees.

- Opportunities should be grasped to allow pupils to personalise aspects of the classroom, eg named lockers or drawers.

- Good quality, child-centric, furniture, fixture and equipment can be used to strongly support learning and indicate that pupils are valued.

Examples

Distinct ceiling

Class-made display

Personal storage

Interesting desk

References

- DeVries R., Zan, B.(1994) Moral Classrooms, Moral Children: Creating a Constructivist Atmosphere in Early Education (Early Childhood Education), Teachers' College Press (31 May 1994), 320 pages
- McMillan, D. (1997) Classroom Spaces & Learning Places: How to Arrange Your Room for Maximum Learning, Charthage, Il: Teaching & Learning Company, Lorenz Corporation.
- Ulrich, C.(2004) A place of their own: children and the physical environment, Human Ecology , Vol. 32, No. 2, pp11-14, October 2004

Individualisation

Connection – a secondary factor

Background

In terms of school design, connection involves pathways between spaces within the school environment. In this case, safe, free movement are basic requirements. Circulation such as hallways and corridors are a costly percentage of a school building. It is noted by Garling et al. (1986) that navigation is made easier by use of landmarks and high levels of differentiation between different parts of the school, together with less complex layouts. Tanner (2009) draws heavily on Alexander's (1979) ideas of design patterns and investigates patterns of movement and circulation at the school level. His study suggests that fine-space orienting information can improve pupil's performance.

Our Findings

Issues around corridors and navigation seem to have some small influence on learning, but they are not as important as other factors and so dropped out in the multilevel modelling (MLM). This is perhaps understandable in primary schools where the pupils tend to spend most of their time in one room. A MLM sub-analysis specifically of impacts on Reading suggests that "corridor libraries" can be beneficial for this activity (see next page). If possible then:

- Corridor width: wider corridors allow ease of movement in crowded conditions and open up possibilities for relieving congestion in classrooms by providing auxiliary storage as has been discussed under "flexibility" .

- Orienting corridor: Orientation around the school can be aided by large and visible pictures, landmarks and abundant daylight with plenty of outside views along the corridors.

Illustrations of corridor width (TOP) and orienting features (BOTTOM)

Too narrow

Wide / clear

Too little information to orient the way

Good: Big display on the wall between each classroom

Checkpoints for designers

- Wider corridors with distinctive features allow safe and easy movement.

- Extra width in corridors adjacent to classrooms can be designed to relieve classroom clutter by accommodating, for example, say, storage cupboards and cloakroom pegs.

- Views to the outside along the corridor can greatly improve pupils' orientation around the school.

- Siting library facilities where they become part of the natural flow of the school appears to be beneficial for Reading progress in particular – see illustration below.

Checkpoints for teachers

- Corridors should be kept clear for circulation and orientating "landmarks" provided.

- Displays outside the classroom on the corridor wall is an efficient way for orientation and avoiding a long institutional-style effect.

- If it is used for storage, congestion of the corridor should be avoided and clear sight lines maintained.

- "Corridor libraries" can be considered – see below.

Examples of "corridor libraries"

References

- Alexander, C. (1979) The Timeless Way of Building, Oxford University Press, New York, NY
- Garling T., Book A and Lindberg E (1986) Spatial Orientation and Wayfinding in the Designed Environment: A Conceptual Analysis and Some suggestions for Post-Occupancy Evaluation. Journal of Architecture and Planning Research, 3, 55-61.
- Tanner C K (2009) Effects of school design on student outcomes. Journal of Educational Administration, 2009. 47(3): p. 381-99.

Stimulation - Appropriate level of
Complexity

Background

Theories suggest that diversity, novelty or atypicality, introduce visual complexity, which, in turn, affects stimulation and arousal. Theories abound as to whether more or less stimulation is good. For example a recent study has shown that children in Low Visual Distraction conditions spent less time off-task and obtained higher learning scores than children in the High Visual Distraction condition (Godwin and Fisher, 2014). They also found that learning scores were higher in the sparse-classrooms than in decorated-classrooms (Fisher et al. 2014). On the other hand, Read et al. (1999) found that differentiated spaces with varying ceiling heights and wall colours supported cooperative behaviour, albeit the effect could become counter-productive if the space became too complex.

Our Findings

Our results strongly indicated that the effect of Complexity is curvilinear, such that high or low levels of complexity produced poorer learning conditions, whereas an intermediate level of visual complexity was optimal.

The cumulative impact of the following room elements were taken into account in delivering visual complexity.

- Visual diversity of the floor layout and ceiling: Enough to stimulate the pupils' attention, but presenting a degree of order.

- Visual diversity of displays: The displays on walls are well designed and organized, probably covering up to a maximum of 80% of the available wall area.

Illustrations of levels of Visual complexity of display

Too little

About right

Too much

**Checkpoints
for designers**

○ Choices in the shape and form of the classroom floor plan can be used to create a reasonable level of visual interest – not boring, but not too dramatic.

○ This can be enhanced or moderated by choices around the ceiling design, where higher, simple forms can "decompress" the space, whereas more complex shapes can add to the complexity, albeit clutter and disorder should be avoided.

**Checkpoints
for teachers**

○ The displays on the walls should be designed to provide a lively sense to the classroom, but without becoming chaotic in feel. As a rule of thumb 20-50% of the available wall space should be kept clear.

○ Placing display materials on windows should be avoided if possible (loss of light), especially if it results in no uncovered areas.

○ In deciding how much extra visual complexity to introduce, the basic characteristics of the space (floor plan and ceiling design) should be taken into account and complemented – see illustrations below.

Example

These classrooms have complexity inherent in their designs – eg the floor plan on the left and the ceiling design on the right.

References

● Fisher, A., Godwin, K., Seltman, H. (2014) Visual Environment, Attention Allocation, and Learning in Young Children: When Too Much of a Good Thing May Be Bad, Psychological Science, May 21, 2014, doi: 10.1177/0956797614533801

● Godwin, K. E., & Fisher, A. V. (2011). Allocation of attention in classroom environments: Consequences for learning. In Proceedings of the 33rd Annual Conference of the Cognitive Science Society (pp. 2806-2811).

● Read, M., Sugawara A., Brandt, J.(1999) Impact of Space and Color in the Physical Environment on Preschool Children's Cooperative Behavior, Environment and Behavior, Vol. 31 No. 3, May 1999 413-428

Stimulation - Appropriate level of

Colour

Background

When discussing colour in an educational context, the choices can be seen as a matter of preferences, or from a functional learning perspective. In terms of preferences younger children do seem to like bright-ish colours (Heinrich 1980, 1993).

A functional approach focuses on using colour to achieve an end result such as increased attention span and lower levels of eye fatigue. For example, Jalil et al. (2012) reviewed how different colours influence: working performance; cause certain behaviours; create negative or positive perceptions of the surroundings and task given; and influence moods and emotions. They concluded that coloured environments have significant effects on pupil's learning activity and their well being.

Our Findings

Colour elements were assessed with low brightness colours (white/pale) at one end of the scale and high brightness colours (red/orange) at the other. When viewed as a functional factor impacting on learning, the stimulation from the use of colour was found to be curvilinear, optimally pitched at a mid-level. The combined effect of the following was taken into account.

O Wall colour and area: This core aspect is curvilinear. Large, brightly coloured areas rated poorly as did white walls with few colour elements. The intermediate case with light walls generally, plus a feature wall in a brighter colour was found to be most effective for learning.

O Against this relatively calm backdrop, additional colour elements in the classroom played a complementary, stimulating role. For example, relatively bright colours on the floor, blinds, desk, chairs and adds extra highlights and flashes of colour.

Illustrations of Wall colours and areas

Too little

About right

Too much

About right

Checkpoints for designers

○ Light walls with a feature wall highlighted in a brighter colour contributes to an appropriate background level of stimulation.

○ The impact on people of a simple white built environment tends to be under-stimulation. This can lead to restlessness, excessive response, and difficulty in concentration.

○ Bright colour on facilities, e.g. floor, shading covering, desk and chairs can be introduced as accents to the overall environment.

Checkpoints for teachers

Given that a mid-level of stimulation is sought for an effective learning environment, it makes sense to:

○ First assess the colour elements in place that cannot be readily changed at a given point.

○ Then decisions can be taken about how much bright colour should be introduced into other aspects, for example backgrounds to wall displays.

○ In doing this, the aim is increase stimulation against a muted background, or calm the feel if it is already rather bright.

Example of range of brightness in colour

Colour brightness

Darkness   Hue   Lightness

Low intensity ———————— High intensity ———————— Low intensity
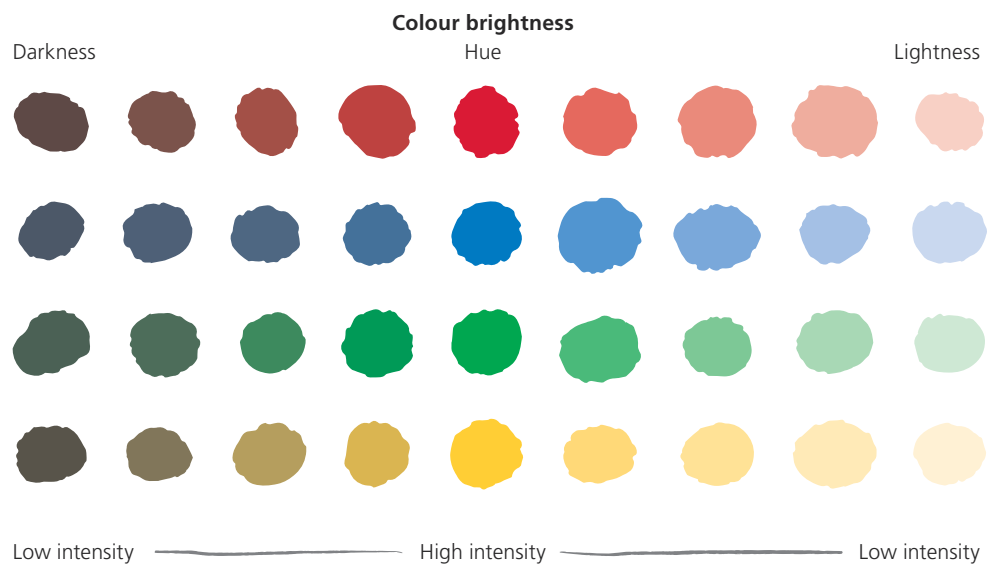
References

● Heinrich, F. (1980), Farbe hilft verkaufen: Farbenlebre und Farbenpsychologie für Handel und Werburg (Colour Helps Sell: Colour Theory and Colour Psychology for Commerce and Advertising). Göttingen, Muster-Schmidt Verlag.

● Heinrich, F. (1992). Gesetz der Farbe (The Law of Colour). Göttingen, Muster-Schmidt Verlag.

● Jalil, N., Yunusb, R., Said, N. (2012) Environmental Colour Impact upon Human Behaviour: A Review, Procedia Social and Behavioral Sciences 35 (2012) 54 – 62.

Conclusions

This report has set out the results of the HEAD study of primary schools. The intractable challenge of moving from an intuitive appreciation of the impact of built spaces on human performance, to actually pinning down evidence was highlighted. Against this background, a novel combination of the broad SIN (stimulation, individualisation and naturalness) framework and the use of multilevel modelling has enabled the impact of the physical environment on the learning progress of primary school pupils to be identified. This evidence base draws on copious data collected from live classrooms and includes the identification of the aspects of the environment that are significant and examples of what is optimal.

It is hoped that the evidence provided will enable designers and teachers to arrange the features of their classrooms to optimise pupils' learning. In this way the classroom design can really be seen as an active part of the facilitation of the learning process. The following checklists summarise the checkpoints for action from Section 5, respectively for designers and teachers.

It should be stressed that these findings are based on data from schools and pupils in England and so they are conditioned by the geographical and pedagogical particularities here. Thus, if they are to be applied elsewhere careful reinterpretation may be needed. That said it seems likely that the principles and issues would broadly translate. The study has also focused on metrics of formal learning progress and, important as these are, there are of course broader objectives within the educational remit. These have not been addressed, but this is not to diminish the importance of aspects, such as the moral or behavioural dimensions of education.

This research has made a break through on the general problem of establishing evidence of the impact of spaces on people as holistically experienced. This has been in the very worthwhile area of primary schools. It is however reasonable to suggest that the ideas and approaches employed may well help gain better understandings as to the optimal characteristics for other types of building used for other activities.

At this point though, we hope that teachers (as clients and users) and school designers are stimulated to take these ideas into their practice and that the result is improved learning spaces for young children studying at school.
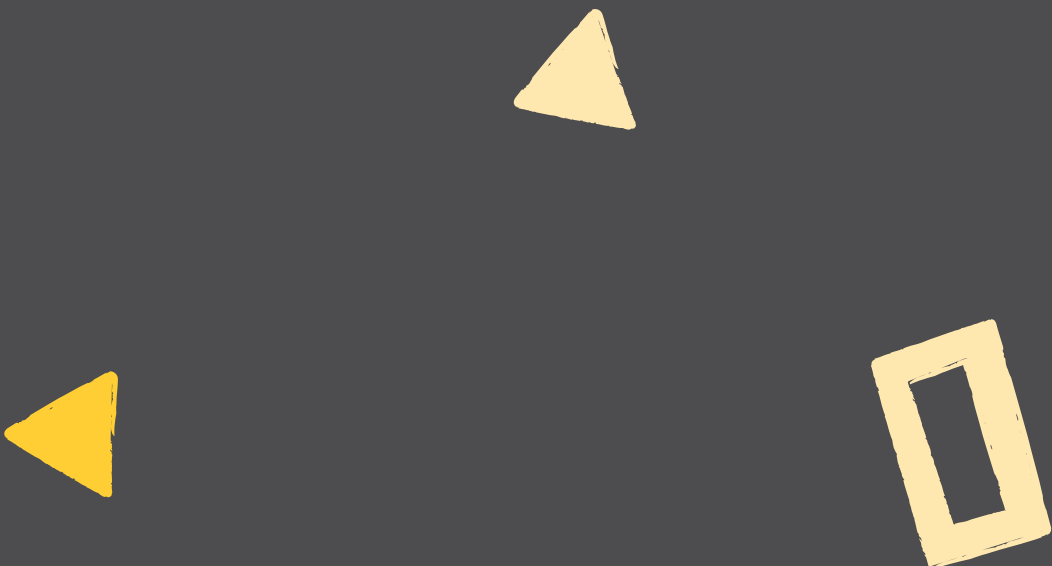
Summary Checklist

The following tables summarise the findings of the HEAD project detailing the checklist of features specifically for designers and teachers. We hope that teachers (as clients and users) and school designers are stimulated to take these ideas into their practice and that the result is improved learning spaces for young children studying at school.

Checkpoints for designers

Naturalness	Light	Advice here is given for UK latitudes but similar considerations will be needed for other locations. Sun glare is more of a problem now because of the use of computer projectors. • Large glazing is welcomed when it is towards the North, East or West which receives abundant daylight and has a low risk of glare during the normal hours of occupation. • Oversize glazing should be avoided when the room is orientated towards the sun's path and in this situation external shading should be provided. • High quality electrical lighting is essential to provide a natural light alternative.
	Air Quality	• Big window opening sizes and at different levels, provide varying ventilation options. Controls should be easy to access and use. • Where possible, increasing the ceiling height can mitigate air quality issues because of a larger classroom volume, but effective ventilation is still needed. • Mechanical ventilation may sometimes be necessary if window options are reduced owing due to noise or security reasons. • An air quality monitor in the room can indicate a problem to the occupants. Air cooling (but not renewal) can mask poor air quality and create cold spots.
	Temperature	• Radiators with thermostats in each room give users better opportunities to dynamically maintain the temperature at a comfortable level. • Underfloor heating systems have merits, but lack of individual room controls and response lags need very careful consideration. • For those classrooms facing towards the sun's path, an external shading device is needed to combat unwanted sun heat.
	Sound (secondary factor)	• Schools should be sited away from busy roads or neighbourhoods, or orientated to mitigate problems. • Planning measures can integrate site features, such as embankments, to diminish the intrusion of noise. If these are covered with plants, then the noise can be further reduced. • Sensitive spaces, such as classrooms can be carefully separated from noisy areas using buffer zones such as toilets, storerooms or corridors.
	Links to Nature (secondary factor)	• Where possible, the view through the window should be plentiful, providing a wide-field vision of landscape and green areas. • The windows sills need to be at or below the children's eye level. • A door directly towards an external play area can give pupils easy access to nature.

Individualisation	Flexibility	• Breakout space attached to the classroom is good for one-to-one and small group support. • A widened corridor adjacent to the classroom should be used for storage so releasing valuable classroom space. • A more complex floor plan provides options for activity areas for younger children (KS1). • A larger area, with a simpler shape, is appropriate / more flexible for older children (KS2). • A big wall area (excluding window and door areas) for display is desirable
	Ownership	• Classrooms should have individual distinctive design characteristics; for example a distinctive shape (L shape; T shape), an added design element (embedded shelf for display, low height window), a distinctive ceiling design or a distinct location, (separate buildings).
	Connection (secondary factor)	• Wider corridors with distinctive features allow safe and easy movement. • Views to the outside from the corridor can improve pupils' orientation around the school. • Siting library facilities, in corridors or atria, where they become part of the natural flow of the school, appears to be beneficial for Reading progress.
Stimulation - Appropriate level of	Complexity	• Choices in the shape and form of the classroom floor plan can be used to create visual interest. • A balance between a space that is too boring and too complex is needed while considering the functionality of the space.
	Colour	• Light walls with a feature wall, highlighted in a brighter colour, create an appropriate level of stimulation. • Bright colours on furnishings, e.g. floors/carpets, shading coverings, desk and chairs can be introduced as accents to the overall environment.

Checkpoints for teachers

Naturalness	Light	• Keeping glazing clear, by minimizing occlusion of the windows can maximise environmental benefits from natural light. • Access and active use of the blinds/curtains is needed to address problems with glare. • Careful siting of high power projector to minimise need to close blinds. • Shrubs or planters placed outside south-facing windows can reduce glare.
	Air Quality	• A typical classroom with thirty pupils will normally need active ventilation within a 1 hour lesson. Avoiding obstructing access the window openings is important. • Excess CO2 can cause drowsiness and inattention and a CO2 meter in the classroom can give teachers an indication of an air quality problem.
	Temperature	• If local temperature control is possible (using a thermostat) the classroom should be kept cool, but comfortable, for optimum learning conditions. • If sun heat gain is a problem and there is no external shading, then active use of blinds and ventilation is essential to mitigate the problem.
	Sound (secondary factor)	• The effect of adding sound-absorbing treatment to rooms is significant. Soft furnishings and posters are good sound absorbers. • Rubber feet on movable furniture can buffer any noise generated, if maintained. • Small carpeted can make a positive difference to noise attenuation.
	Links to Nature (secondary factor)	• Views through windows of green areas, thought to be of benefit, can be hindered by occlusion by window displays and furniture. • Natural elements in the classroom such as plants, wooden chairs and /or desks allow pupils to experience natural elements.

Individualisation	Flexibility	• Well-defined and age appropriate learning zones are important to facilitate learning. • Younger pupils need several well-defined zones for play-based learning activities. • For older pupils simpler space configurations support more formal teaching. • Lower height furniture provides more wall area available for varied displays.
	Ownership	• A classroom that includes pupil-created work in displays will provide a sense of ownership. • A classroom that is distinctly different (using displays) creates a sense of familiarity. • Allowing pupils to personalise aspects of the classroom, such as lockers, coat pegs or drawers, creates a sense of belonging. • Quality ergonomic furniture and equipment can be used to create a child centred space.
	Connection (secondary factor)	• Ideally corridors should be kept sufficiently clear for ease of circulation. • Distinctive displays outside the classrooms or at junctions create orienting landmarks and avoid an institutional-style effect. • "Corridor libraries" are both orienting and a good use of wide corridors spaces.
Stimulation - Appropriate level of	Complexity	• A mid-level of Complexity is sought for an effective learning environment. • Displays should be designed to provide a lively sense to the classroom, but without becoming chaotic. As a rule of thumb 20-50% of the avilable wall space should be kept clear. • In deciding how much extra visual complexity to introduce, the basic characteristics of the room should be taken into account.

	Colour	• A mid-level of stimulation over all is sought for an effective learning environment.
		    - First assess the colour elements in place that cannot be readily changed
		    - Then decisions can be taken about how much bright colour should be introduced into other aspects
		• The aim is increase stimulation in a dull classroom, or reduce it if it is already too bright.

Appendix A:
Hypotheses tested

Design principles	Design parameters	Indicators		Factors	
Naturalness	**Light**	A	The quality and quantity of natural light the classroom can receive.	1	Glazing orientation
				2	Glazing area / floor area
		B	The degree to which the lighting level can be controlled	3	Quality of the electrical lighting
				4	Shading covering control
	Sound	C	The frequency of the noise disturbance	5	Noise from the school outside
				6	Noise from the school inside
		D	The degree to which the pupils can hear clearly what the teachers say	7	Length/width
				8	Carpet area of the room
	Temperature	E	The quality and quantity of sun heat the classroom receives	9	Orientation and shading control
		F	The degree to which the central heating system can be controlled	10	Central heating control
	Air quality	G	The degree of respiration that affects the CO_2 level in a fully occupied classroom	11	Room volume
		H	The degree to which air changes can be adjusted manually	12	Opening window size and position
				13	Mechanical ventilation
	Links to nature	I	The degree to which the pupils can get access to natural elements	14	Access to nature
		J	The degree to which views of nature are available through the window	15	View out

Design principles	Design parameters	Indicators		Factors	
Individualisation	**Ownership**	K	The degree to which distinct characteristics of the classroom allow a sense of ownership	16	Distinct design features
				17	Nature of the display
		L	The degree to which the FF&E are comfortable, supporting the learning and teaching	18	Quality of the furniture, fixture and equipment (FF&E)
				19	Quality of the chairs and desks
	Flexibility	M	The degree to which the pupils have an appropriate provision of space	20	Classroom floor area and shape, KS related
				21	Breakout and storage space attached to the classroom
		N	The degree to which the classroom and wall area allows varied learning methods and activities	22	Learning zones, KS related
				23	Wall area for display opportunities
	Connection	O	The presence of a wide pathway and orienting objects with identifiable destinations	24	Corridor width
				25	Orienting corridor
Stimulation, Appropriate level of	**Complexity**	P	The degree to which the classroom provides appropriate visual diversity	26	Visual diversity of layout and ceiling
		Q	The degree to which the display provide appropriate visual diversity	27	Visual diversity of display
	Colour	R	The degree to which the 'colour mood' is appropriate for the learning and teaching	28	Wall colour and area
				29	Furniture colour
				30	Display colour

Appendix B:

Test for confounding teacher effects

In assessing the results of the HEAD study about the impact on pupils' learning of the physical classroom environment, there is a legitimate question as to whether there is any confounding influence linked to the characteristics of the teachers. Owing to the sensitivity of the data it was not possible to collect information directly on teacher performance, which would have provided the best way to address this question.

As far as possible within this study, measurements were taken of hard architectural elements of the classroom design. Thus, many measures, such as window size and orientation could not be influenced by teacher effectiveness. Some measures, however, do have more subjective components, for example 'display colour' which is an element within the colour parameter. So, an experiment was designed, with the data available, to explore whether these softer measures do indeed have any elements that are influenced by teacher effects. The null hypothesis for the test is that there is no confounding of teacher effects with environmental effects. The test, if it confirms the null hypothesis, indicates that evidence had not been found of a confounding influence from the teacher.
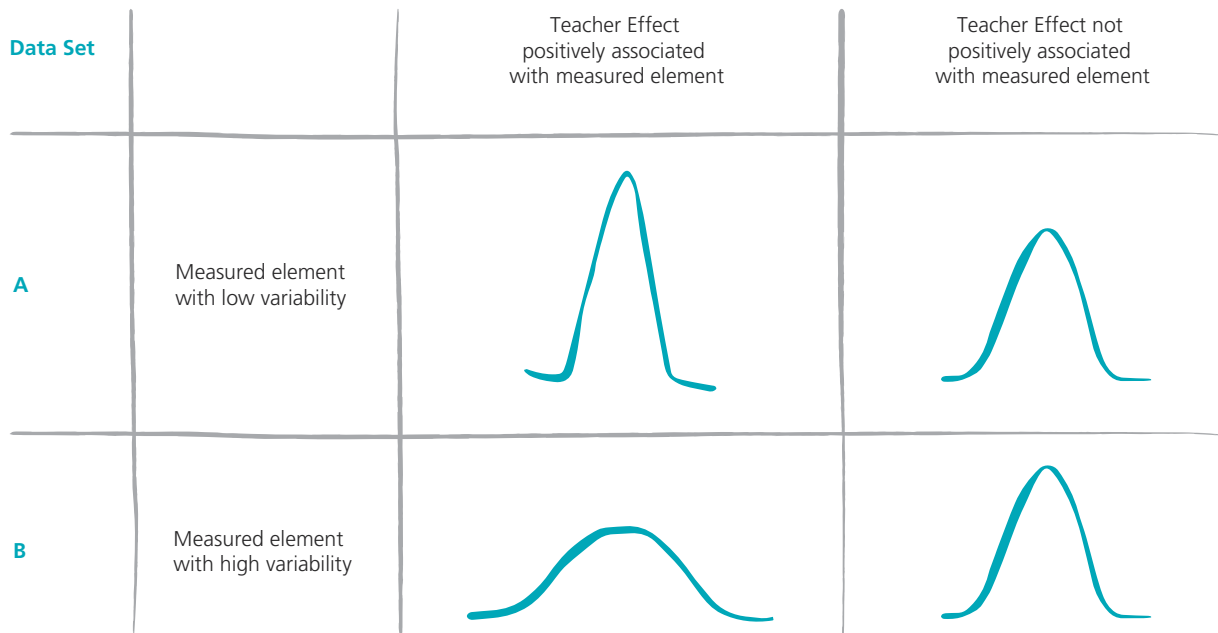
The possible teacher effect was investigated by looking at the variability in one element of the measured classroom environmental parameter and comparing it to the variability in pupil performance as determined by the Overall Improvement statistic. The data were split into two groups: group A contains data of schools where the within-school variability in the measured element was low; group B where the within-school variability in the measured element was high. To focus on the issue at hand, the two groups were matched for number of schools and classrooms, and also the mean value of the measured element. In effect the two groups of schools were being used to create two samples of teachers in order to test if the teachers are responsible for the effect and not the measured element.

There is an implicit assumption in this analysis that teacher effects would dominate the variability of the performance statistic if they were in anyway contributory, over the single measured element. This is a reasonable assumption because, as discussed by Hattie (2009), overall teacher effectiveness and schooling contribute roughly 50% of the total variability in pupil outcomes, so is a major contributor, whereas the single measured element would only be expected to have a very small effect on its own.

Table 1 below shows the two groups (A with low variability in the measured element and B with high variability). The first column of curves then shows the expected distribution of pupil performance if the teacher effect is confounded with the measured element, namely a difference in variability across Groups A and B. Whereas the second column shows what could be expected if there is no confounding, that is, no significant difference in variability.

Performance Data from Overall Improvement

Data Set		Teacher Effect positively associated with measured element	Teacher Effect not positively associated with measured element
A	Measured element with low variability		
B	Measured element with high variability		

The logic is that if teacher effectiveness is positively associated with the measured element effect then sample A would be expected to have lower variability in teacher effectiveness than sample B, and therefore sample A would be expected to have lower variability in performance than sample B.

Thus, a test was carried out for lower variability in performance in sample A than sample B, using a one-sided test of equality of variances, using the Levene's test in particular. If a lower variability was not found in sample A than sample B (on the basis of the test) then it could be concluded that teacher effectiveness is not positively associated with the classroom measured element, and therefore that, in the original analysis, the estimated environmental effect is indeed not confounded with teacher effectiveness.

Qualification: assuming that teacher effectiveness is not negatively associated with the classroom measured element effect.

Results

Four measurement elements from within the Complexity and Colour parameters were chosen to apply the above confounding test, namely: Room Diversity, Display Diversity, Wall Colour and Area and Display Colour. These were chosen to be the measures that were most likely to be affected by teacher choice. In all these four cases evidence was not found that the variability in the performance in sample A was lower than sample B at the 1% significance level. Therefore it was concluded that these environmental effects are not confounded with variations in teacher effectiveness.

References

● Hattie J (2008) Visible learning: A synthesis of over 800 meta-analyses relating to achievement, Routledge, Abingdon, 392 pp, ISBN 978-0-415-47618-8

Appendix C:

Modelling Procedure

This material adds some detail to the description of the analysis given in Section 2. A full explication of the analytical process is given in a paper in the international "Building and Environment" journal.

Once the hypotheses given in Appendix A had been constructed and the data had been collected, measures of the physical environmental factors, rooted in that data, were compiled. A 5-point rating scale was used in each case to indicate the degree to which it was thought the factor in that classroom would support a pupil's learning activity, e.g. 5=very good; 1=very poor. For example, we measured the window and door opening size (towards the outside) of each classroom as an indicator to assess the ventilation situation. Those with the biggest opening size are rated 'very good' while those with the smallest opening size are rated 'very poor'. Thus, the scales were calibrated by our (diverse) sample, which makes sense as we were seeking the variation in the impacts of these features across this sample.

Then the analysis followed two broad steps. First the influence on learning of each of the environmental factors being studied was addressed separately through bivariate analysis, linking, for example, the impact of light to learning progress. Then, once the measures likely to be in play had been identified, and any inadvertent inter-correlations had been minimised, a multi-level analysis of their combined effects was carried out (more details of the multi-level modelling is given below). This did lead to changes in the relative importance of the factors suggested by the bivariate analysis. The reasons for this are two-fold. First, the dynamic between the factors themselves. Second, the fact that a range effects linked to pupil characteristics (such as special educational needs) could be factored out, leaving a clearer picture of the "net" impacts of the physical design aspects. Our focus is on the latter, but it can be noted that in our data set pupils with English as an additional language (EAL) tend to progress faster than other pupils, pupils qualifying for free school meals (FSM – a measure of deprivation) progress more slowly and pupils with special educational needs (SEN) progress much more slowly. Thus, it can be seen that concentrations of certain categories of pupils could confuse matters, but the MLM enabled this to be dealt with.

Pupils

Pupils in English primary schools are assessed on their progress in reading, writing and maths through the National Curriculum (NC) using NC levels which can be converted into a widely accepted equivalent NC points system. In this work progress was assessed using teacher assessed pupil data by using levels at the start of the academic year and levels at the end of the academic year. The level data was converted into NC points and the points progress over the academic year calculated. Points from the reading levels, the writing levels and the maths levels were added together to get an overall points progress for each pupil.

Multi-level Modelling

Owing to their shared environment, it could be expected that the progress between pupils in the same classroom would be more correlated than pupil progress between pupils in different classrooms. For this reason we used a type of linear regression model that allows data to be clustered in groups, called a multi-level model (MLM). A two level model was used with pupils at Level 1 nested within classrooms at Level 2.

The model had overall progress as its dependent variable and was initially fitted with Level 1 or pupil variables. The pupil variables included in the analysis were pupil start NC level, age, gender, Free School Meals Status (FSM), Special Educational Needs status (SEN) and English as an additional Language status (EAL).

Correlations between overall progress and each
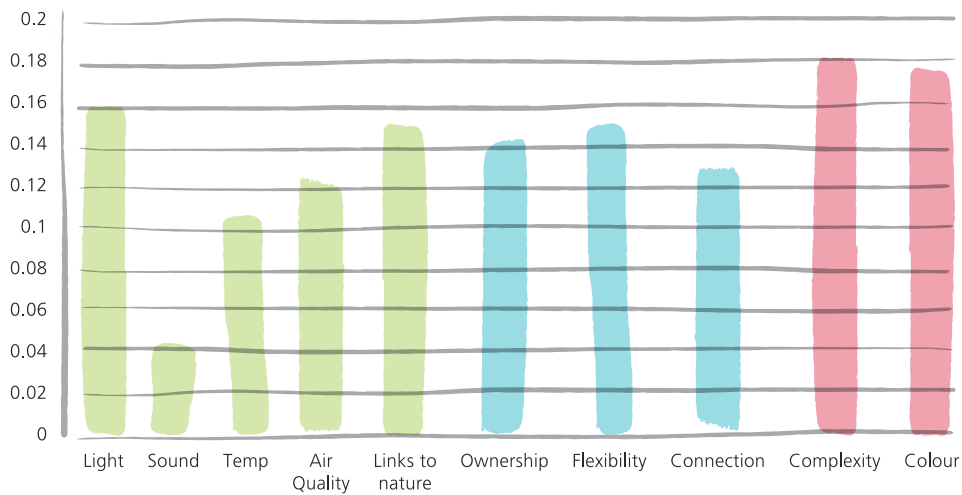
The second step in the modelling procedure was to fit the classroom environmental variables: Light, Sound, Temperature, Air Quality, Links-to-Nature, Ownership, Flexibility, Connection, Complexity and Colour. The impact of these Level 2 factors in explaining variations in learning progress could then be isolated.

Contribution of the physical factors to the observed

Percentage Improvement (%)

Classroom
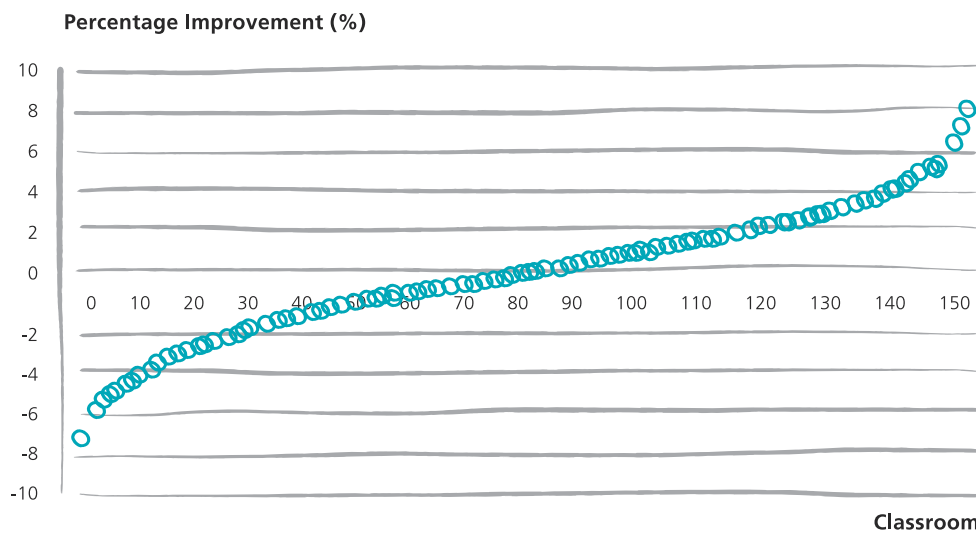
The MLM process identifies which factors significantly improved the predictive power of the model through their inclusion. This is how the seven main physical environment factors were identified. The final model describes the relative significance of the factors to each other, and also relates them to the pupil level factors. By fixing the pupil level factors to their mean scores and doing likewise with the unexplained variability at the class level it was then possible to model the theoretical impact of each of the classrooms on the learning of an "average" pupil. From this the range of variation in learning progress (in NC points) owing to just the physical characteristics of the classrooms could be calculated and scaled against the overall variation across the pupil sample. This ratio provided the 16% value for the contribution of the physical factors to the observed variations in learning progress. This process also enabled the impact to be calculated, in NC sublevels, of moving an average pupil from the least effectively to the most effectively designed classroom, that is, 1.3 sub-levels.

Appendix D:

Implications from Sub-analyses

Further Work

The results as reported so far involved the factors that were significant when investigating the overall progress of pupils. The overall progress was a metric complied by adding pupil progress in Reading, Writing and Maths together. When investigating the individual subject models separately, the weightings for the classroom environmental parameters were subtly different.

**Reading
Writing Maths
Investigations**

In the reading model Connection was found to be a significant parameter. Upon examination of the schools it was found 11 of the 27 schools had wide corridors or atria spaces that had been utilized as library spaces. The average reading progress was significantly higher in schools that contained these 'Corridor Libraries'.

In the Writing model the parameter Link-to-Nature was found to be significantly correlated with writing improvement. It has been noted in previous research that natural spaces can have an impact on cognitive ability (Wells, 2000) and increased attention (Martensson et al., 2009).

With maths progress the parameter that had the largest coefficient by far in the regression model, and which therefore had the biggest possible influence was flexibility. The individualization parameter of ownership was also significant. The combination of these two parameters being significant points towards a classroom that is highly individualized for the particular pupils as being the most ideal for the best possible progression in maths.

**SEN, FSM
and EAL**

In the data collected for this study there were a total of 667 pupils with special educational needs (SEN). Five of the classrooms in the sample had no SEN children, so 148 classrooms were included in the separate SEN modelling study. There were 17 classrooms which contained 9 or more SEN pupils. Modelling with the 667 pupils independently produced results that were significantly different from pupils overall. The SEN pupils appear on average to be more sensitive to the colour within the classroom. For SEN pupil reading improvement sound was also found to be significant.

There were 775 pupils who were given as having free school meals (FSM) for the year of the study. There were 12 classrooms with no FSM pupils, leaving 141 classrooms in the FSM modelling study. There were classrooms in the study that had up to 50% of their pupils on FSM. As with the SEN pupils the level of stimulation parameter of colour appeared to have a larger effect within the classroom than for the average pupil.

Out of the whole data set there were 874 pupils who were designated as having English as an additional language (EAL), and 90% of these EAL pupils were attending schools in urban environments. The modelling results for the EAL pupils were markedly different from the whole data set as the Links-to-Nature parameter was significant. It would seem that the Links-to-Nature is clearly an important influence for the predominantly urban pupils in this study. Whether this is an EAL effect or urban effect is not known, however previous research has shown urban children, particularly girls, who live nearby nature have significantly better self-discipline (Taylor et al., 2002).

References

● Wells NM (2000) "At Home with Nature: Effects of ''Greenness'' on Children's Cognitive Functioning".
Environment and Behavior. 32: 775

● Martensson F, Boldemann C, Soderstromc,M, Blennowe M, Englund J-E, and Grahn P.(2009)
"Outdoor environmental assessment of attention promoting settings for preschool children". Health & Place. 15: 1149–1157

● Taylor A F, Kuo F E and SullivanW C (2002) "Views of nature and self-discipline: Evidence from inner city children".
Journal of Environmental Psychology. 22 (1-2): 49-63

Lead Investigator
Professor Peter Barrett
Peter qualified originally as a chartered building surveyor and then gained an MSc in Construction Management and a PhD in the management of professional practices. He has been at Salford for 24 years during which time the built environment group there became the strongest in the UK and he fulfilled roles from Head of School to Pro-vice Chancellor for Research. He was also President of the Conseil International du Batiment for three years to 2010. Peter has pursued an interest in the value of construction within society for many years, which led to a focus on Senses, Brain and Spaces, itself leading to the HEAD project to study the impact of school spaces on pupils' learning rates, within a neuroscience schema. Peter is active on the UK and EU research strategy panels for construction. He has recently taken up the role of Research Director for the multidisciplinary Institute for Dementia at the University of Salford.

Team Member
Dr. Yufan Zhang
Her focus was on the identification of the classrooms' environmental design in order to better understand the characteristics of beneficial spaces for pupils and teachers.

Dr. Fay Davies
Fays' role was to liaise with schools for the collection of the pupil performance data of the project and the subsequent statistical analysis and multilevel modelling.

Dr. Lucinda Barrett
Lucinda has been involved in the collection of data in the classrooms studied within the HEAD project, as well analysing the soft data collected via teachers themselves.

Contact Details:

School of the Built Environment
Room 400, Maxwell Building
University of Salford
Salford, M5 4WT, U.K

Tel: +44 (0) 161 295 5588
Email: p.s.barrett@salford.ac.uk
Skype: prof_peter_barrett
Web: http://www.ri.salford.ac.uk/peterbarrett/m/?s=14

If you would like to find out more of this project:

- The full results are now freely available at http://dx.doi.org/10.1016/j.buildenv.2015.02.013 - P. Barrett, F. Davies, Y. Zhang and L. Barrett (2015), 'The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis'. Building and Environment, Vol 89 (2015) pp118-133.
- Barrett, P., Barrett, L., Davies, F., (2013) Achieving a step change in the optimal sensory design of buildings for users at all life-stages. Building and Environment, Vol 67, pp. 97-104.
- Barrett, P., Zhang, Y., Moffat, J., Kobbacy, K., (2013) An holistic, multi-level analysis identifying the impact of classroom design on pupils' learning, Building and Environment. Vol 59, pp 678-689.
- Barrett, P., Barrett, L. (2010) The Potential of Positive Places: Senses, Brain and Spaces, Intelligent Buildings International 2: 218-228.
- Barrett, P., Zhang, Y. (2009) Optimal Learning Spaces Design Implications for Primary School
  - 2 pp45, , Design and Print Group, University of Salford, Maxwell 100, Salford, UK.