A sound foundation? What we know about the impact of environments on learning and the implications for Building Schools for the Future

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This paper reports on a literature review conducted in the UK for the Design Council and CfBT (Higgins *et al.*, 2005) which looked at the evidence of the impact of environments on learning in schools. We have reviewed the available evidence regarding different facets of the physical environment and provided an analysis based on different areas of effect, including the extent to which different facets interact (positively and negatively) with one another. Our conclusions suggest that, although the research often indicates the parameters of an effective environment, there is an overall lack of empirical evidence about the impact of individual elements of the physical environment which might inform school design at a practical level to support student achievement. However, at a secondary level of analysis, there are indications that environmental change can be part of a catalytic process of school development and improvement. The implications of these findings for Building Schools for the Future will be discussed.

Introduction

In common with other economically developed countries with a history of publicly-funded education, the UK has a sizable resource of school buildings to maintain and perhaps improve. After a period of little new school building, often judged as under-investment (Clark, 2002), the current government has committed itself to some concerted spending: 'working together to create world-class, 21st century schools—environments which will inspire learning for decades to come and provide exceptional assets for the whole community' (Building Schools for the Future, 2004). This has

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led many to discuss the priorities for new schools and, more broadly, to consider the influence the environment might have on learning. However, when government ministers address this issue, their comments often imply that the effect of students' surroundings on their learning is obvious. For instance, announcing further new funding for school environmental projects through the Targeted Capital Fund (TCF), Education Secretary Ruth Kelly claimed that this represented 'another big step towards our goal of ensuring that all young people are being taught in buildings that can enhance their learning and provide the facilities that they and their teachers need to reach their full potential' (DfES, 2005).

Although there are those with architectural backgrounds (for example, Dudek, 2000) who support this assumption that aspects of the physical school must affect behaviour and influence learning, these ideas do not appear to be firmly based on empirical evidence. However, over the past half century, a range of studies have been conducted, particularly in the USA, which have relevance for this problem of determining what elements of the environment cause what effects on learning. Given the current enthusiasm in government circles, and beyond, for evidence-based educational policy and practice (Thomas & Pring, 2004), it would seem appropriate for those involved in Building Schools for the Future (BSF) to consider such work.

This article reports on a literature review recently carried out by the Centre for Learning and Teaching at the University of Newcastle upon Tyne on behalf of the Design Council and CfBT, two British charitable bodies that are involved in the current efforts at school regeneration. It provides a synthesis of existing knowledge in a complex field which draws on a number of disciplines, from the purely educational, to psychology, environmental and buildings design and ergonomics, with a variety of paradigms for research and reporting. Inevitably, work has been summarised and the detail of particular studies cannot be reflected in this short account. Our purpose here is to make clear where there is empirical support for change and where there is conflict, inconsistency or complexity. Throughout the research and reporting process we have maintained a strategy of giving the greatest prominence to recent, relevant research which has a clearly reported empirical base.

This review began by searching databases using relevant search terms (see Appendix 1), providing us with a large number of books, journal articles and other material, of which over 200 were studied in depth. It became immediately clear that there has been more research in some areas than in others. We found that despite general interest in and ideas about some areas relating to learning environments, there is frequently a paucity of clear, replicable empirical studies, particularly research which addresses specific elements of the environment. Certain case study evidence exists, but there are issues of how replicable or generalisable these findings are. Moreover, some studies overlap with environmental considerations but do not have changes to the learning environment as the primary focus and therefore do not report in sufficient detail for comparisons to be made with other studies.

It has been pointed out that typical school buildings and classroom layouts vary between countries in ways that are related to understandings and philosophies of education as well as to material resources (Alexander, 2000). However, research

specifically concerned with the effect of the learning environment on students tends to be carried out in Western Europe and, particularly, in the USA. Although certain regions have produced notable contributions relating to particular aspects (e.g. Germany and Scandinavia on air quality; Britain on external noise) it is in the USA that the general issue of the learning environment has been most thoroughly addressed (Clark, 2002).

Our review looks at the impact of learning environments and it was important from the outset to distinguish between the various kinds of impact. Table 1 is a summary table which divides the impacts found in the literature into five headings:

Attainment: improvements in curriculum attainment measured by standardised tests or exams, or as monitored by teacher observation.
Engagement: improvements in levels of attention, more on-task behaviours observed, decrease in distracted or disruptive behaviour.
Affect: improvements in self-esteem for teachers and learners, increased academic self-concept, improvements in mood and motivation.
Attendance: fewer instances of lateness or absenteeism.
Well-being: impacts on the physical self, relating to discomfort as well as minor and major ailments.

In line with other theorists and researchers in this field (e.g. Moos, 1979; Weinstein, 1979), we have assumed that these elements are inter-related and will affect each other. So, for example, the physical environment of a school might have an impact on attendance through influencing student affect, as when an unattractive school is suggested to fuel truancy (Hallam, 1996) or through affecting well-being, in the way that poor ventilation is proposed to result in ill-health (Rosen & Richardson, 1999). However, it seems likely that some of these elements, such as well-being, will tend to be affected directly, whereas others, such as attendance and achievement, are more likely to occur at the ends of chains of effect, even if these chains are not always described.

Table 1 divides the evidence base into three broad slices: the first where improvements to the environment have impacted positively on one or more of the five kinds of effect, the second where evidence of effect is more equivocal or conflicting and the third where there is evidence that poor quality environmental elements have a negative effect. It is particularly important to distinguish between the first and third bodies of evidence, since there is a tendency to make simplistic assumptions about causal relationships and we do not mean to imply that because (for example) poor air quality is associated with poor concentration and low attainment that it is necessarily the case that improving air quality in a classroom which is already within 'normal' ranges will improve the concentration or attainment of pupils there. There is, as one would expect, a great deal more evidence of impact on the 'lower extremes' of provision and very limited evidence of impact for tinkering with 'good enough' environments.

For example, reviews of the consequences of aspects of the physical environment tend to conclude that acoustics and noise are important factors in a school environment (Fisher, 2001; Schneider, 2002; Earthman, 2004). Schneider commented that in general the research is 'consistent and convincing: good acoustics are fundamental

to good academic performance' (2002, p. 6). Yet, considering the research base would tend to imply that here 'good' should be understood as good enough, or not actually deficient, an over-extension of this recommendation will not be helpful.

More generally, Earthman (2004) concluded that while inadequate school buildings cause health problems, lower student morale and contribute to poor student performance, he was not convinced that schools need necessarily be any more than adequate. Rutter *et al.*, who found no relationship between school physical factors and a range of learning and behavioural outcomes, commented that, 'It was entirely possible for schools to obtain good outcomes in spite of initially rather unpromising and unprepossessing school premises' (1979, p. 178). Stricherz pointed out that 'Research does show that student achievement lags in shabby school buildings … but it does not show that student performance rises when facilities go from the equivalent of a Ford to a Ferrari—from decent buildings to those equipped with fancy classrooms, swimming pools, television-production studios, and the like' (2000).

As Table 1 demonstrates, the picture is extremely complex and it is not possible to engage with the detail of debates in individual fields of, for example, illumination or ergonomics in this paper. More detail is available in the full report (Higgins *et al.*, 2005) and the full references there will give the interested reader somewhere to begin their own exploration of the literature. This paper highlights those areas of school environment where education managers and policy makers might fruitfully concentrate their efforts. The sections which follow will unpick the evidence for individual environmental elements at a school and classroom level, before turning to implications both for the renovation and improvement of existing schools and the building of new schools.

Detrimental environments

This is the easiest area to address, in that clear links have been drawn between poor quality school buildings and classrooms and poor outcomes for learners and there is evidence that bringing these environments into the 'normal range' of acceptable provision reverses the detrimental effects. For example, Berry (2002) reported a study of the renovation of a very run-down elementary school in the USA, which found that, after environmental improvements were made, there were increases in attendance and standardised test results, as well as various indications of improved morale and mood. However, even in this section the messages are sometimes complicated by the fact that classrooms, schools and the communities in which they are physically and socially placed are complex systems which are nested within one another (Bronfenbrenner, 1979).

Air quality

Earthman (2004) rated temperature, heating and air quality as the most important individual elements for student achievement. In the school renovation project

Table 1. Summary table of evidence of effects

	Attainment	Engagement	Affect	Attendance	Wellbeing
Improvement of environmental element leads to improvement	Light (daylight) Build quality (pathways and positive outdoor space)	Low ceilings (pupil co-operation vs. perceptions of crowding) Colour (contrast walls) Storage (open shelves, more time on task)	'Beautiful' spaces High ceilings (teacher satisfaction) Display (pupil self esteem)		
Equivocal evidence	Room arrangement (depending on goal of lesson/interaction)	Ergonomic furniture Noise (learned helplessness) Temperature, ventilation, air quality (distraction of air conditioning) Desk arrangement	Colour Lighting Noise (mood) Build quality (renovation)	Temperature, ventilation, air quality (disputed) Build quality (ownership vs short term 'wow' factor) Lighting (disputed)	Ergonomic furniture
Poor quality environmental elements have detrimental effect	Air quality Noise Safe, healthy surroundings	Air quality Noise	Noise (context dependent) Overall build quality	Air quality Safe, healthy surroundings	Air quality (esp. asthma) Storage (open shelves, dust, allergens) Lighting (eyestrain, headaches) ICT (lighting, posture)

mentioned above (Berry, 2002), the repair of the heating and ventilation system was a central part of the environmental improvements that were carried out. Two studies (Young *et al.*, 2003; Buckley *et al.*, 2004) mention the importance of these issues in reports which address the needs of particular US states' schools, while Fisher (2001) and Schneider (2002), in detailed reviews of the available evidence, similarly rated these factors as likely to affect student behaviour and outcomes.

The importance of ventilation in educational establishments continues to be emphasised (Kimmel *et al.*, 2000; Khattar *et al.*, 2003), while the inadequacies of indoor air in schools continue to be reported (Lee & Chang, 2000; Kimmel *et al.*, 2000; Khattar *et al.*, 2003) and linked to ill-health (Ahman *et al.*, 2000). Most of these studies assume that air-related health problems are self-evidently problematic, but the carefully constructed study of Rosen and Richardson (1999) went further by linking poor air quality to absenteeism. They found that reducing the number of particles in the air—and so improving air quality—in a nursery school resulted in reduced child absence, which clearly would have implications for learning and academic achievement. In contrast, the Heschong Mahone Group (2003) reported that operable windows and air conditioning had no effect on school absenteeism. However, this apparent contradiction could be an instance of trying to reconcile a study of rectifying a poor environment, in the nursery school, with attempts to improve upon an adequate environment in the schools.

Noise

The research into the effect of living or learning in noisy surroundings was initially driven by concerns about exposure to chronic external noise, such as that due to aircraft or road traffic. In a review of the area, Stansfeld and Matheson discussed the possibility of health and psychological problems and concluded that, 'The evidence for effects of environmental noise on health is strongest for annoyance, sleep and cognitive performance in adults and children' (2003, p. 253). Other reliable findings indicated that chronic noise exposure will impair cognitive functioning and a number of studies have discovered noise-related reading problems (Evans & Maxwell, 1997; Haines *et al.*, 2001b), deficiencies in pre-reading skills (Maxwell & Evans, 2000) and more general cognitive deficits (Lercher *et al.*, 2003).

There has been some discussion about the mechanism for the widely reported reading deficits. It has been observed that pausing by teachers during bursts of external noise produces an effective reduction in teaching time (Weinstein, 1979), which has been put as high as 11% (Rivlin & Weinstein, 1984). Although there is interest in noise annoyance (Kjellberg *et al.*, 1996; Boman & Enmarker, 2004) and links to mood (Lundquist *et al.*, 2002, 2003), it seems there is also a more direct cognitive mechanism (Haines *et al.*, 2001a). Hygge (2003) reported that various noises (recordings of aeroplanes, road traffic and trains) appear to interfere with the encoding stage of memory and that this is not mediated by distraction or mood. Evans and Maxwell (1997) argued that the reading deficits result from problems with language acquisition and, specifically, with speech perception. A related suggestion is that, in

general, impairment in performance is partly explained by the interference of any noise with inner speech, suggested by laboratory experiments (Poulton, 1978), while Knez and Hygge (2002) found that irrelevant speech is a particularly distracting noise.

The evidence relating to distraction fuels concern that many have about internal or ambient noise levels in classrooms, even where there is not particularly loud external noise. Shield and Dockrell (2004) found that external noise levels did not generally affect levels of classroom noise, which were mainly dependent on internal factors such as the nature of the classroom activity, number of children etc. It must be noted, though, that they measured the noise levels with the classroom windows closed, and that when the children were engaged in silent reading the external noises became more significant and possibly distracting. Moreover, they found that background noise in unoccupied classrooms was above guideline levels. Other researchers have drawn attention to these problems of inadequate acoustics (Addison *et al.*, 1999; Lundquist *et al.*, 2002) and proposed various solutions such as increased carpeting (Tanner & Langford, 2002), sound amplification systems (McSporran *et al.,* 1997) and ceiling hangings to dampen reverberation (Maxwell & Evans, 2000).

Lighting

One line of research in this field is concerned with health issues such as headaches, eyestrain and fatigue, which are often exacerbated by inadequate lighting and/or shielding from glare associated with the use of ICT, particularly personal computers and interactive whiteboards. To overcome these complaints, Karpen (1993) suggests the use of full spectrum polarised lighting as it is glare free and flicker free. As there is an increased use of computers in schools the idea of creating glare free lighting is important (Barnitt, 2003).

Areas of debate or equivocal evidence

It is not possible to do justice to the complexity of debate in specialist areas in an article of this length but we hope in this section to offer a sense of how important the contextual factors in individual schools may be to making decisions about environments.

Room arrangement and furniture

Horne-Martin (2002; Horne, 1999) has carried out observational studies in classrooms and argues that style of teaching and room organisation are linked, although it is not clear which is cause and which is effect. There is evidence (Ahrentzen & Evans, 1984) that more open classrooms do have some direct effect on how teachers teach, but Rivlin and Rothenberg (1976) found that this was not as dramatic as might be expected: despite being encouraged by the policies of the school and the lay-out of the classroom to be more flexible and less traditional, many of the teachers they

studied stayed in one place, essentially 'taught from the front' and did not move the furniture. In general, as Weinstein and David pointed out, 'open-space, in and of itself, does not have a universal effect' (1987, p. 12) while Canter and Donald considered that in studies comparing open and traditional environments, 'the essential element was the school's educational philosophy and physical layout, not merely the physical layout on its own' (1987, p. 1292).

Some writers see observations about behaviour in open-plan settings as linked to the more general issue of architectural determinism. Cooper, himself architecturally trained, warned that 'Those who offer guidance on the planning of buildings tend to assume that there is some necessary relationship between the design of a building and the behaviour of those who occupy it' (1981, p. 125), a position which he went on to reject comprehensively. Away from research on school environment, it has been found (Brennan *et al.*, 2002) that open-plan offices do not necessarily affect staff behaviour. Findings like these, and some of those of Horne (1999), imply that human beings tend to resort to simply coping with the given environment rather than actively managing it and this may be related to users not being involved in the design process and thus not 'owning' their space.

One of the more basic variables that can be altered in the classroom is the arrangement of the students' desks and chairs, and this issue has been quite well researched, frequently using experimental designs, and debated. Rows of desks are considered to be appropriate to individual work and increase time on task (Galton *et al.*, 1999). The research which specifically compares rows and tables (Wheldall *et al.*, 1981, Wheldall & Lam, 1987; Hastings, 1995) suggested that less attentive and less successful pupils are particularly affected by the desk arrangement, with their on-task behaviour increasing very significantly when seated in rows instead of at tables. It is pointed out by these authors that the vital mediating element between the physical environment and improved classroom climate could be the reduction in negative interactions between teacher and student, since the student in the rows arrangement is able to concentrate and so provokes fewer admonishments. This plausible chain of events has relevance for any alteration to the physical environment, although it perhaps has most immediate relevance to the improvement of inadequate surroundings.

Within the rows arrangement, there seem to be differences in student involvement dependent on position, with an 'action zone' of increased involvement across the front and down the middle of the room. There is some discussion about whether this is more accurately characterised as a 'T' shape or as a triangle (Marx *et al.*, 2000) but there is agreement about the existence of such a zone. This is observed even with random allocation of seats (Weinstein, 1979; Gump, 1987). Moore *et al.* (1984) found evidence that such differences originate in the questioning and attentiveness of the teacher rather than students' behaviour. Many educationalists, on the basis mainly of teaching experience, recommend a 'horse shoe' formation where students can see each other and the teacher (Alexander, 1992; McNamara & Waugh, 1993; Galton *et al.*, 1999). Although Horne-Martin (2002) argued this is a very controlling and teacher dominated approach, Marx *et al.* (2000) found that more questions are asked by children when seated in this arrangement rather than in rows.

Considering the classroom arrangement more generally, Nash (1981) found that the thoughtful organisation of an infant classroom to fulfil educational aims, instead of for organisational convenience, facilitated learning and enhanced cognitive development. In a similar study, Moore (1986) argues that the arrangement of pre-school environments seems to affect behaviour. However, the general experience of enrichment projects that include environmental aspects (e.g. Hohman & Weikart, 1995) would seem to suggest that arrangement of equipment is part of a much more complex network of pedagogical aims, beliefs and circumstances, which it is therefore difficult to consider in isolation. In this vein, Loughlin and Suina proposed that the arrangement and positioning of material is a 'tool to support the learning process' (1982, p. xv). Another issue related to the arrangement of a classroom is that concerns about privacy are sometimes voiced by children (Rivlin & Rothenberg, 1976), and Ahrentzen and Evans (1984) argued that teachers could help by arranging furniture to produce private areas. However, they also found that an increased number of such places in a classroom seemed to co-occur with the children being less satisfied with provision of privacy.

The examination of ergonomic seating and positioning has been well researched in the workplace, but it has tended to be ignored in classrooms (Yeats, 1997). However, some children contributing to *The School I'd Like* (Burke & Grosvenor, 2003) mentioned inadequate furniture and there is some literature relating to classroom furniture (e.g. Aagaard-Hansen & Storr-Pauben, 1995; Marschell *et al.*, 1995). A study which took anthropometric measurements of students' body dimensions (Parcells *et al.*, 1999) concluded that there was a substantial degree of mismatch between students' body dimensions and furniture that they use. Such a mismatch was also found by Panagiotopoulou *et al.* (2004). Given the difference in size between school children, particularly in secondary schools, adjustable furniture might seem sensible (suggested by Zandvliet & Straker, 2001) and in fact has been advocated for some time: Donovan (1921) has a design for an adjustable desk and seat. However, any observation in schools demonstrates the failure of such ideas to become accepted wisdom in the UK.

Knight and Noyes considered children's behaviour and sitting positions when using traditional classroom furniture and ergonomically designed furniture. They found that children showed a 'significant improvement in on-task behaviour and a marked change in sitting positions following the introduction of the newly designed furniture' (1999, p. 747). Linton *et al.* (1994) did not observe any different sitting positions in the children in their study when using ergonomically designed furniture, but they suggest that students need guidance on proper use of such furniture. The children did comment that the ergonomically designed furniture was more comfortable, as did children in a further study conducted by Troussier.

Troussier (1999) investigated levels of back pain when children use traditional and ergonomically designed furniture but concluded that there was no significant difference in prevalence of back pain. It has been argued that back pain does exist among school children (Murphy *et al.*, 2004) but some researchers emphasise that back pain is not solely due to inappropriate classroom furniture and that other factors

are relevant (Troussier *et al.,* 1994; Grimmer & Williams, 2000). It can be concluded that, overall, there is preference for the ergonomically designed furniture in the studies (Marschell *et al.,* 1995; Yeats, 1997; Troussier, 1999; Panagiotopoulou *et al.*, 2004) but it is more difficult to draw conclusions about the effect on well-being, behaviour or learning of traditional furniture.

Temperature, ventilation and air quality

The findings on these linked areas, especially fundamental ideas about temperature control, tend to come from the USA and we might question whether the levels of effect might translate to schools in a more moderate climate such as that of the UK. Additionally, as mentioned previously, studies of the improvement of air quality probably vary in their initial conditions, making comparisons difficult. Furthermore, it is notable that air conditioning, ventilation and heating systems are found to contribute quite distinctly to the level of classroom noise (Shield & Dockrell, 2004). This is considered too noisy by many researchers in that area and suggests the potential for conflict between demands for certain physical elements to be prioritised over others.

   Air quality is closely linked by some researchers to childhood asthma: for example, Smedje and Norback (2001) argued that since irritants and allergens collect in dust, it might be advisable to avoid particular sorts of 'fleecy' furnishings and open shelving and to increase the frequency of cleaning. It is evident that the demands of clean air might come into conflict with the teacher's desire to provide a comfortable, cosy and welcoming classroom, in which resources are readily available to independent, active learners.

Lighting

There is some evidence that lighting affects mood and attitude, which might then influence performance (Knez, 1995; Jago & Tanner, 1999). Veitch (1997) however, argued that lighting has no effect on mood or performance, while Knez (2001) found that females were more perceptive to light than males, with males and females performing differently in different kinds of lighting. In terms of attendance and wellbeing, the Heschong Mahone Group (2003) asserted that physical classroom characteristics, including lighting, do not affect student attendance, while other researchers, for example Hathaway (1994), suggested that there is a correlation between absenteeism and lighting. Hathaway goes further on the aspects of lighting than other researchers, linking lighting to incidence of dental cavities and gains in height and weight.

   A recent review (Veitch & McColl, 2001) reflected the complexity of lighting types, the difficulty of deciding whether the focus should be upon luminosity or chromatic distinction, to give but two of many factors, and recommended: 'As a practical matter, ergonomists, along with lighting designers, architects, facilities managers and other lighting specifiers, should end their search for the ideal fluorescent lamp for all

circumstances. … [C]hoices should be made with an eye to their suitability for the task, the building, the local culture, and the lighting system performance, including energy efficiency and aesthetic judgements' (Veitch & McColl, 2001, p. 274).

Colour

Aesthetic considerations link directly to colour: depending on the age of children, different colours are considered stimulating; younger children prefer bright colours and patterns, while adolescents prefer more subdued colours (Engelbrecht, 2003). However, Pile (1997) suggested strong, warm colours for young children, and warned against the use of intense primary colours. The existence of different preferences for particular colours has been suggested between males and females (Rosenstein, 1985; Radeloff, 1990; Khouw, 1995; Read *et al.*, 1999), although other writers argue there is no difference in colour preference between genders (Ou *et al.*, 2004 a, b, c). However, Sundstrom (1986) pointed out that those experiments that determine people's colour preferences generally involve small patches of colour that are viewed for a short period. He argued that the findings do not show what colours people prefer their offices (or their classrooms!) to be painted.

Bross and Jackson (1981) carried out a study on girls in grades 7–9 which found that the participants made fewer errors when working in cubicles painted in their preferred colour, while time to complete tasks changed minimally. Hamid and Newport (1989) carried out a study with preschool children and they concluded that the children demonstrated more physical strength and positive mood in a pink coloured room than in a blue coloured room. However, the results obtained from this study contrast with the tranquilising effect pink is supposed to have on incarcerated adults (Schauss, 1985; Russell & Snodgrass, 1987).

To conclude, however, it might be sensible to bear in mind the comment made by Sundstrom (1987) about colour in the workplace: 'Color is one of the least studied aspects of the physical environment, but it nevertheless remains the topic of some of the most optimistic claims about morale and efficiency' (p. 751).

Noise

Cohen *et al.* (1980) found evidence of raised blood pressure and signs of learned helplessness due to noise, although these problems have not been found by other studies (such as Haines *et al.*, 2001a). In terms of problems of annoyance and mood, research (Kjellberg *et al.*, 1996; Stansfeld & Matheson, 2003) has found that factors such as predictability, control and judged necessity influence how annoying people find particular noises. However, there are limits to the judgements about the effect of noise with several studies finding that participants can be apparently mistaken about the effect of the noise situation on their performance (Salame & Wittersheim, 1978; Knez & Hygge, 2002). In addition, there are some limited suggestions that some individuals might be more sensitive to noise than others (Zimmer & Ellermeier, 1999; Belojevic *et al.*, 2001).

Build quality

Maslow and Mintz (1956) found that participants in an 'ugly' room made significantly less positive judgements about photographs than did the participants doing the same task in a 'beautiful' room and it is clear that the provision of new buildings or the renovation of old ones can have marked effects (Sommer & Olsen, 1980; Berry, 2002) on motivation and engagement. However, it is likely that these effects tend to be short term, based on the initial 'wow factor' and if each cohort of users does not have the opportunity to personalise or 'own' the space, a decline in engagement would be expected. This concern is mentioned in the study of Killeen *et al.* (2003) which looked at exhibiting children's work as part of permanent tiling, but wondered how a feeling of ownership could be continued once the available space had been used up.

Adding value to environments

There are some areas where there appears to be good evidence to support changes to 'already adequate' environments in order to bring about improvements in learner and teacher affect, engagement and attainment. We would nevertheless advise caution, since even the best of these studies are based on limited numbers of schools and often reflect the culture of US schools—leading to potential pitfalls for uncritical adopters in the UK context.

Build quality

Ahrentzen and Evans (1984) found that higher ceilings in classrooms produce decreased perceptions by both teachers and children of crowding, with the height of the classroom ceiling correlating significantly with teacher satisfaction with the room. However, Read *et al.* (1999) found that ceiling height affected cooperative behaviour among preschool children, with the children displaying higher levels of cooperative behaviour in classrooms with lower ceilings. Earthman argued that a particular problem with older schools is that their high ceilings 'may negate the benefit of better lighting' (2004, p. 20), while higher ceilings can also increase acoustic problems due to reverberation. Therefore, although changing ceiling height could be proposed as a way to add value to an environment, it is still difficult to be certain, on the basis of the evidence, in which direction it should be altered. Presumably the appropriate decision depends on other aspects of the situation, such as existing lighting or acoustic problems, and perceptions of users about comfortable and appropriate ceilings.

Tanner (2000) provided a number of suggestions about elements of school design which might be particularly important. Among the four features of his school design assessment scale which correlate with student achievement are 'pathways' and 'positive outdoor spaces'. The former refers to buildings and grounds which encourage ease of movement, presumably avoiding feelings of crowding. With reference to the latter factor, Tanner was convinced of the benefit of well designed and maintained

outdoor spaces and his findings do suggest that they might contribute to student academic performance. Certainly outdoor areas are noticed: Maxwell's (2000) student respondents criticised the rather inadequate outdoor area at their school.

Lighting and colour

It has been argued that daylight increases achievement (Heschong Mahone Group, 2003; Earthman, 2004). However, having solely a daylight source in the classroom is often not practical or possible. Benya suggested that for 'lighting to be effective, daylight must be supplemented by automatically controlled electric lighting that dims in response to daylight levels' (2001, p. 1). Barnitt (2003) suggested that good lighting can only be achieved by a combination of direct and indirect lighting. A common complaint in the classroom is eye fatigue and in order to relieve this, Engelbrecht (2003) suggested that the end wall of the classroom behind the teacher should be a different colour from the other walls. This idea is also offered by Pile (1997) and Brubaker (1998). There is some suggestion that colour contrast may help concentration upon whiteboards, though this is dependent upon other lighting and glare within the room.

It must be noted that many of the assertions about the benefits of light and colour originate in the ideas of architects and designers, and so are based more on professional expertise than on empirical research. However, research into user perceptions does tend to concur with the underlying assumption that these factors are noticed and valued. Maxwell (2000) found that children thought colour was important and that the colour of the walls in their school was uninviting and boring. However, in this study, Maxwell also found that teachers and parents did not share these concerns. Burke and Grosvenor (2003) further emphasise children's preference for colour. In their book, *The School I'd Like*, many children mentioned colours and lots of colours. One 15-year-old student described her school as 'a giant magnolia prison. I want colours'.

Display and storage

The case is frequently made that display of children's work is beneficial, with all users of the school studied by Maxwell (2000) agreeing that display of students' work made the school more welcoming. Although Alexander has questioned the wisdom of displays being pursued as 'ends in themselves' (1992, p. 38), and Dudek (2000), with an architect's eye, regarded the display of children's work as making the visual aspect 'cluttered', other writers argue that they increase feelings of ownership and involvement, leading to improved motivation (Killeen *et al.*, 2003). Interestingly, Maxwell's (2000) study demonstrated that perception of the adequacy of display may vary between school users. She found that although the parents, teachers and students all appeared to appreciate the display of work, the adults thought the school achieved this while the students were less satisfied.

There are various ways of displaying students' work. McGonigal (1999) advocated giving each individual a personal space, while Killeen *et al.* (2003) argued for the

importance of permanence, with children's artwork actually incorporated into the fabric of the school. They found that in a school which achieved this through extensive tiled murals, children were considerably more positive about the school, compared to a control school. However, this study only shows a correlation, not a causal link, between inclusive artwork and positive attitude.

Loughlin and Suina (1982) discussed how the storage and arrangement of materials may be ignored, but argued that the methods used affect how, and whether, items get used and are returned afterwards. There is some empirical evidence to suggest that accessible, well-thought out storage leads to more time spent learning (Loughlin & Suina, 1982; Gump, 1987).

Implications for Building Schools for the Future

Physical elements in the school environment can be shown to have discernable effects on teachers and learners. In particular, inadequate temperature control, lighting, air quality and acoustics have detrimental effects on concentration, mood, wellbeing, attendance and, ultimately, attainment. It would therefore seem worthwhile bringing these elements up to levels of adequacy; in many cases simply by conforming to standards and regulations, which quite recently was not being achieved by a quarter of secondary schools (Ofsted, 2001).

In her review of the effects of the physical environment in education, Weinstein was quite cautious about effects on student achievement. She concluded that although the 'weight of the evidence suggests that design features can have a significant influence on students' *general behaviour* … and on their *attitudes*' (1979, p. 584), it is difficult to find reliable evidence of a definite effect on achievement. She pointed out, however, that the 'more positive attitudes and behaviours may eventually result in improved achievement' (1979, p.599). More recent reviews have tended to be more optimistic about positive evidence for direct as well as indirect effects of the environment (see, for example, Moore & Lackney, 1993), yet many of these effects seem to be observed as deficits in performance in schools with poor environments (e.g. Schneider, 2002; Young *et al.*, 2003), a conflation of 'remediation' and 'value added' which we have already problematised.

There is currently a great deal of public money being spent on improving the quality of school environments through new building, retro-fitting and improving older schools, the introduction of new ICTs into schools (for example, interactive whiteboards: Hall & Higgins, 2005; Smith, *et al.,* 2005; Wall *et al.*, 2005) and it is part of the work of this review to inform this process. However, beyond the necessity of meeting basic standards, there is not enough evidence to give clear guidance to policy makers on how to set priorities for funding, or to evaluate the relative value for money of different design initiatives. There are a small number of environmental improvements which are associated with improvements in attainment but it is important to remember that once provision reaches a reasonable standard, the complexity of environmental interaction comes into play. It is difficult to come to firm conclusions about the impact of learning environments because of the multi-factorial

nature of environments and the subsequent diverse and disconnected nature of the research literature. The empirical research that exists on the impacts of environment on teaching and learning tends to focus much more upon some elements (such as noise) and to fail to synthesise understandings (such as the implications of noise and temperature research tend to conflict). To give one example, an attempt at improving acoustics in a classroom by deadening echo noise through the use of hangings might achieve the primary aim but may also decrease the air quality in the classroom, through increased dust and allergen particles being held in the fabrics.

More broadly, it is not possible on the basis of the available evidence to weigh the potential benefits of environmental improvements against alternative uses for these monies, such as professional development or the provision of teaching assistants. It would be useful if future research directly and explicitly addressed this issue of comparison and cost-benefit analysis.

However, the conclusions of our review are not that investing in environments is pointless but that if investment is to be most fruitful we must examine critically the question of just how the environment is supposed to produce effects on its users. Clearly this is not a simple matter of architectural determinism. The experiences of open plan schools and offices demonstrate this, and the active role of human beings is emphasised by environmental psychologists (e.g. Gifford, 2002). The relationship between people and their environment is complex and therefore any outcomes from a change in setting are likely to be produced through an involved chain of events. It is the defining and understanding of these mediating chains that is key and must take account of issues relating to ownership, relevance, purpose and permanence. It is reasonable to suggest that positive changes, selected by the teachers and learners, might tend to beget further positive changes in a 'virtuous cycle', whereas negative elements might cause a vicious cycle of decline. Externally imposed changes, regardless of their merit, might be expected to have less of an effect than changes brought about through genuine consultation and an inclusive design process. Large-scale investment, particularly that which is trumpeted as 'future-proofed', will necessarily be less organic and rooted in the needs of specific communities than smaller-scale projects. It is important to focus on the meaning of schools in different communities and to look clearly both at what is intended by 'consultation' and what is delivered.

Environmental psychologists often separate the aspects of the total environment into three parts: the physical, social and the cultural (Horne-Martin, 2004). Although the major concern of those planning and building schools is likely to be the physical elements, any expectations about the impacts of changes in the physical environment on cognitive and affective measures must be based on an understanding of the complexity of schools. Schools are systems in which the environment is just one of many interacting factors: including, but not exclusive to, pedagogical, socio-cultural, curricular, motivational and socio-economic. Rivlin and Wolfe (1985) highlighted the consequences for planning and design of features in the wider society, particularly the power relations of designer and user. Getzels (1975) argued that changes in the typical US classroom, from rows of desks in a rectangular room through a circle of tables to open classrooms, reflect changes in the cultural conception of learning.

Many writers have noted the related idea of the symbolic meaning of a particular environment (Proshansky & Wolfe, 1975; Rivlin & Wolfe, 1985; Maxwell, 2000) and such ideas are clearly in the minds of those who attempt to revive schools perceived as failing. For example, the headteacher at a recently opened school asserted, 'This is more than just another school in Hackney: it is a symbolic school, an emblem, saying these places should be where children from all backgrounds in inner city areas should come and be successful' (Ward, 2004).

Linked to this, a number of writers (e.g. Moore & Lackney, 1993; Young *et al.* 2003) have argued that the built school environment can be altered and is open to improvement so that, even if such changes only make a small and uncertain difference to performance, they can be morally defended, particularly in schools where the students are disadvantaged in other less immediately alterable ways. Interestingly, Gump urged that 'change, for its own sake, can be a stimulating experience' (1987, p. 703). This comment returns us to the potential catalytic effects of the design process, since without planning and design there is a tendency to be unreflectively conservative. As Rivlin and Wolfe commented, 'It is rare for a person to move a chair once it has been placed—even in one's own living room' (1985, p. 7).

It is crucial, therefore, for the growing trend of user involvement in environmental design to become embedded in normal practice. It has been argued (Moore, 1979; Asprino *et al.,* 1981) that, because lay and expert perceptions and opinions about architecture vary, it is necessary to involve ordinary users. The idea that considering, and trying to impact upon, the nature of the school environment is empowering has been referred to by a number of writers (David, 1975; Horne, 1999; Horne-Martin, 2002). Dudek (2000) and Clark (2002) recommend the genuine involvement of students and teachers in the design process. At the time of experimentation with open plan education, a contemporary book (IDEA, 1970) argued that all staff need to be involved to realise the potential of the space, while 'there must be extensive involvement of the parents in the planning as well as in the implementation of the programs; otherwise, the new school is doomed before it is even opened' (p. 20). Rivlin and Wolfe were especially positive about the ideas and vision of children. They described an occasion where not involving pupils in a classroom innovation fatally undermined it (the loft structure that 'suddenly appeared', 1985, p. 200) and, furthermore, regarded the involvement of children in design projects as important in overcoming the conservatism of many adults.

Sundstrom (1987) reported some findings of increased satisfaction with environments designed through user involvement, and points out that this satisfaction could be due to the involvement itself, the resulting building being actually better, or perhaps both. However, he is quite cautious about representing such involvement as a panacea and clearly there are ways and degrees of involvement, to which Clark (2002) alluded. In a classic article, Arnstein (1969) used a typology to describe how people might be involved in the planning and operation of public programmes. This views participation as ranging from 'manipulation', where ideas are basically imposed on users, through 'informing' and 'consultation', which can be of limited worth if done in isolation, to the genuine participation of 'partnership' and 'citizen control'.

Such a one-dimensional typology could be further developed by considering at which stages participation is sought, from initial design ideas through development of plans to the process of installation and the management of change, as well as post-change 'snagging' and re-design and, vitally, who is involved. This seems especially relevant to school design, where there are distinct groups of users. Furthermore, it is beginning to be acknowledged that involving children in decisions relevant to them is necessary (Clark *et al.*, 2003) while the BSF Building Bulletin includes a commitment to consult 'all potential users in the community' (DfES, 2002, p. 63). To investigate the results of such intentions, research is needed into the different ways in which design processes are managed, together with greater engagement with understandings of involvement, consultation and partnership.

Many researchers have developed questions and rating scales to measure users' opinions and perceptions. These could be used to involve school users in a design process and have, in any case, allowed a bank of knowledge to accumulate about the concerns of particular users. However, there can be problems of subjective responses failing to match up with objective measures (Salame & Wittersheim, 1978; Knez & Hygge, 2002; Evans & Stecker, 2004). Evans and Stecker cautioned that 'suboptimal environmental conditions may harm individuals without causing negative subjective awareness' (2004, p. 162), while Gifford gave the opinion that 'it should not be necessary to demonstrate that something in the environment fries our brains or causes insanity before it is replaced' (2002, p. 311). Taken together these two arguments imply that users' perceptions should be seen as a sufficient, but not a necessary, indication of problems or benefits of a particular environment. A development from previous generic environmental questionnaires may be the use of tailored ICT-based tools such as Event Mapper (http://intu.cem.dur.ac.uk/datamap/), which give individual schools and communities the opportunity to explore the strengths and weaknesses of their environments and to establish local priorities.

More research is needed about the effects of the design process on teachers' and learners' locus of control with regard to other aspects of school life. There is an implication in many studies that the empowering process of re-designing and taking ownership should spill over into motivation and empowerment in other areas, encouraging creativity and experimentation in curriculum, raising motivation towards academic and social goals. However, there has been limited longitudinal work looking at the positive effects of change, although there is an emerging literature on the negative impacts of externally generated curriculum and pedagogical change (e.g. Angus, 2004; Fisher, 2004; Rossides, 2004).

The key message for policy makers from this review is that considered and targeted environmental improvement is worthwhile but that the solutions will vary widely across the country. The history of school building programmes (Woolner *et al.*, 2005) warns us that the interactive whiteboard and the atrium could be the typing suites and flat roofs of the middle decades of the 21st century. Overall, the evidence is consistent with regard to the importance of user engagement in defining and solving design problems in schools and a necessary consequence of this is the realisation that design solutions will be individualised, organic and local. Indeed, the most successful are

likely to be those which are seen as interim solutions and which have within them elements of flexibility and adaptability for new cohorts of learners and teachers, new curriculum demands and new challenges.

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Appendix 1

The search strategy and results

Search terms	Databases						
	Article First	ECO	World Cat	Web of Science	BIDS	BEI	ERIC
physical learning environment	16	143	317	321	7	13	
school building							51
noise + education /teaching / school	91	73	1400	305	2	18	
temperature + education/teaching/ school /classroom	146	110	2499	271	3	3	
light + education	396	1113	3535	42	149	9	
light + classroom	29	113	328	14	11	3	
colour + education/classroom	33	94	1873	108	10	36	24
colour + learning / mood / motivation	2	11	0				
effect of colour	13	1					
decoration + learning	1						