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INFORMATION PAPER

Indoor school environments, physical activity, sitting behaviour and pedagogy: a scoping review

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Physical activity levels in children are low and sitting time high, despite the health benefits of regular physical activity and limited sitting. Children spend a large proportion of their time at school, hence school-based interventions targeting physical activity and sitting behaviour may be important. Whilst some aspects of school buildings, their layout and furniture may influence children's physical activity and sitting, these effects could be intertwined with pedagogical approaches. This scoping review aims to identify gaps in the research literature regarding the influence of the indoor school environment on pedagogical approaches and on physical activity and sitting. In primary schools, it was found that physical activity can be integrated into lessons with some benefits on academic behaviour and possibly academic performance. Overall, however, the role of the indoor built environment is poorly investigated, although a handful of studies suggest that a radical change in primary school classrooms may increase physical activity and that stand-biased desks may be promising. This study provides a contribution to the emerging research fields of 'active design' from the perspective of indoor school design, highlighting a dearth of research, especially on sitting and for secondary education, and a lack of relevant conceptual frameworks.

Keywords: active design, built environment, children, education, pedagogy, physical activity, schools, sedentary behaviour, sitting

Introduction

The benefits of regular participation in physical activity (PA) (defined as 'any bodily movement produced by skeletal muscle that results in energy expenditure'; Caspersen, Powell & Christenson, 1985, p. 126) are well document in young people (5–17 years old), as acknowledged by the World Health Organisation (WHO) (2011). PA may benefit the health of young people by aiding in the prevention of non-communicable disease risk factors (Strong et al., 2005). Moreover, PA may benefit psychological health by aiding in the reduction of anxiety and depression and

contributing to the improvement of self-esteem (WHO, 2011). Evidence also exists that PA may have a positive impact on academic performance, including academic achievement, cognitive skills and attitudes to school work (Rasberry et al., 2011). It is recommended that young people and children older than five years accumulate at least 60 minutes of moderate to vigorous physical activity (MVPA; *e.g.* brisk walking) daily. Vigorous-intensity activities (*e.g.* swimming, running, etc.), including those that strengthen muscle and bone, should be incorporated at least three times per week (WHO, 2011). There is increasing evidence that, independent of PA, sedentary behaviours (SB) (*i.e.* sitting) are associated with negative health outcomes, suggesting that reducing sitting may be associated with lower health risks in young people. For example, research shows that daily viewing of television in excess of two hours is associated with reduced physical and psychosocial health (Tremblay et al., 2011). Whilst there is some controversy as to whether sitting time is independently associated with adiposity in children (Chaput et al., 2012; Tanaka, Reilly, & Huang, 2014), evidence of the co-occurrence of the low levels of PA and high levels of sitting (television viewing time in this case) suggests that public health strategies targeting both might be necessary (Anderson, Economos, & Must, 2008). Despite the key health benefits of PA and of low levels of sitting, research shows that young people are more inactive than recommended in several countries including the UK (Griffiths et al., 2013) and the US (Centers for Disease Control and Prevention (CDC), 2014). Furthermore, a review of intervention studies aimed at increasing overall PA levels in children concluded that such interventions have had only a small effect (Metcalf, Henley, & Wilkin, 2013).

During term time, school-aged children spend a large proportion of their time in school and, hence, schools can be considered an obvious target for increasing PA and reducing sitting in children. However, a study based in England found that primary school children's (aged 9–10 years) levels of PA are lower when pupils are at school in comparison with other times of the waking weekday (Smith et al., 2012). Other research on primary school children (aged 8–11 years) showed that only a small percentage met PA guidelines during physical education (PE) (Nettlefold et al., 2011). That study concluded that schools should complement PE with PA models that increase PA opportunities across the school day (Nettlefold et al., 2011). It is thus important to consider whether effective strategies can be found to 'nudge' school children into being more active, whereby the physical environment often plays an important role in 'choice architecture' approaches to changing population health behaviour (Hollands et al., 2013). 'Nudging' refers to the idea of strategically presenting choices in order to affect behaviour predictably without forbidding any options or significantly changing economic incentives (Thaler & Sunstein, 2008). It also implies relying more heavily on subconscious mechanisms or habits, rather than on motivation or intentions, in order to affect behaviour. Within this context, there is a growing body of research-based evidence on the importance of 'active design', *i.e.* designing the built environment to promote or at least facilitate PA – complemented by the need for facilitated access to healthy foods (New City Department of Design and Construction (NYC DCC), 2010). There is some evidence that aspects of site selection/design, building programming/design, as well as building elements could influence PA across various building types (Zimring, Joseph, Nicoll, & Tsepas, 2005). For example, the choice of using stairs as opposed to lifts might be affected by several aspects, such as the visibility of stairs, their aesthetics (*e.g.* lighting, artwork) or position within the building (Zimring et al., 2005). With respect to the impact of the built environment on SB, research is, however, still in its infancy.

In the context of research on PA within schools, the role of the environment – both social and physical – has been increasingly investigated, often against the background of the obesity challenge. In the published literature the terms 'physical' and 'built' environment are often used interchangeably. Generally, however, the physical environment could be considered as a broader construct encompassing any man-made aspects (at any scale, *e.g.* man-made parks or food vending machines) as well as 'natural' ones (*e.g.* vegetation). Harrison and Jones (2012) reviewed the evidence for associations between the physical school environment and diet, PA and adiposity. The study also developed a conceptual framework for understanding these associations, starting from an energy balance approach, where food represents 'energy in' and 'energy out' is represented by PA (light, moderate and vigorous PA). The framework considers for each of these factors (PA, and food accessibility/availability) the links with the physical school environment at three scales: (1) the 'neighbourhood': facilities and properties of the environment beyond but around the school; (2) 'school grounds and design': the design of the school building and its grounds; and (3) 'school facilities': both larger-scale more permanent facilities such as obstacle courses or vegetable gardens and smaller-scale, less permanent features such as games equipment, playground markings and vending machines. Overall the review paper shows that the presence, size and design aspects of school grounds and facilities influence the PA of school children. It also highlights that 'modifications to the physical environment are likely to be more effective when coupled with supportive social and educational changes' (Harrison & Jones, 2012, p. 10). Whilst the framework is a useful starting point, it does not

specifically address SB or sufficiently clarify whether 'class PA' primarily or solely refers to PE or also includes regular class time.

It is important to highlight that within the school setting, PA can be accumulated during PE classes, recess or break times (*e.g.* through adult-led or 'free' play in the courtyard) and during class where there might be the potential for light-intensity physical activity (LPA), such as standing or stretching. Conversely, lessons have the greatest potential for SB, although this might also occur at break times and lunch. However, the majority of research on PA in schools has so far concentrated on MVPA and its determinants, with a particular focus on PE and break times. Aspects of the playground and its attributes have been especially investigated within this context (Broekhuizen, Scholten, & de Vries, 2014). There is, however, a growing awareness that PA should not solely be framed as MVPA, and that it might also be desirable to foster a culture of accumulating activity across the whole spectrum of PA levels, and reducing sedentary time throughout the day (Story, Nanney, & Schwartz, 2009). The Comprehensive School Physical Activity Programme (CSPAP), developed by the US Centers for Disease Control and Prevention (CDC) – partly reflects this model: it is a multi-component approach by which school districts and schools use all opportunities for students to be physically active, meet the recommended 60 minutes of MVPA, and develop the knowledge, skills and confidence to be physically active throughout their lifetime (CDC, 2013). The programme advocates going beyond PE during school to meet the daily 60 minutes. It highlights that students can participate in PA during recess, integrated into classroom lessons, breaks in and outside the classroom, and lunchtime clubs or intramural programmes. It appears, however, that the focus is primarily on MVPA. Nonetheless, the CSPAP suggests examples of PA breaks in the classroom (including a five-minute stretch break, a form of light PA) and cites successful programmes that have integrated PA into classroom lessons. For example, the Take10! Programme[1] is designed for primary schools and aims to help children understand the importance of PA (as well as of other healthy behaviours, such as healthy eating), whilst reducing SB, improving attention and promoting structured PA breaks. Each grade-specific kit is divided by academic content area, *e.g.* maths, social studies, etc. Studies concluded that the Take10! programme demonstrates that integrating movement with academic sessions in primary school classrooms is feasible, helps students focus on learning and enables them to realize improved PA levels (Kibbe et al., 2011). The programme website states that the Take10! approach requires no special equipment or tools and allows students to be active within the space limitations of a standard-size classroom (LSI Research Foundation, 2012). Hence, in this case the classroom's physical environment appears to be framed as neutral, neither enabling nor inhibiting PA.

In summary, the benefits of regular PA and of limiting SB on health are fairly well established. Some research exists on the role of the physical/built environment in facilitating or encouraging active behaviours of children at school, with the focus primarily on MVPA within PE lessons or break times and on the characteristics of playgrounds and outdoor school environments. There is now growing awareness that increasing PA and discouraging SB at school may also have a positive effect on academic performance. Whilst some pedagogical approaches have been developed to facilitate the integration of PA into the curriculum and more broadly into the whole school day, it is unclear to what extent the built environment, especially its indoor component, plays a neutral, facilitating or inhibiting role. Thus the question arises as to whether the links between the indoor school environment, PA/SB and pedagogy have been adequately investigated. This scoping review brings together a cross-disciplinary team of education, built environment and PA experts to review published evidence in each disciplinary domain to identify the impact of the indoor built environment on pedagogical approaches, PA and SB of children during school times. The review is primarily a gap analysis of existing research, focusing on aspects of the indoor environment not solely or mainly dedicated to PE and/or MVPA.

Methods

General framework for the scoping review and initial search criteria

This study adopted a scoping review approach. Although no universal definition exists for this review type, generally it is applied to 'mapping' a research field (Levac, Colquhoun, & O'Brien, 2010). The team largely followed the main stages for a scoping review discussed in Levac et al. (2010): (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) charting the data; (5) collating, summarizing and reporting the results; and (6) stakeholder consultation (optional and not carried out in this review). Given the broad scope of this study, it was agreed only to review abstracts rather than full papers. Accordingly, a suitably broad research question was firstly identified, accompanied by a clear scope of enquiry, that informed the selection of the initial inclusion/exclusion criteria and keywords for electronic searches. The broad research question initially selected was:

> What is the impact of the built environment and of pedagogical approaches on the levels of physical activity and sedentary behaviour of children during school times, especially during lessons and breaks?

In order to identify relevant studies, search criteria were established. While the focus was primarily on lessons and breaks indoors, the initial inclusion/exclusion criteria were broad in order to allow for a more in-depth consideration of the literature. These covered: (1) age group: 2–11 and 11–16 years old; (2) date of publication: anytime; (3) geography and research language: any geographical location; papers written in English; and (4) format and types of publication: research reports, guidelines, review articles, research articles, doctoral dissertations and other online sources as appropriate. Exclusion criteria were: further education, breakfast clubs, after-school classes, holiday, summer, and Sunday schools. Accordingly, inclusion search terms were: built environment, school design, pre-school, physical activity, movement, sedentary behaviour, school, classroom, teaching, learning, pedagogy and exercise. The study utilized OvidSP as a primary source, and discipline-specific journals as a secondary source. OvidSP is an online database from Ovid that holds over 1300 peer-reviewed journals, 4500 e-books and 100 databases in the fields of medicine, nursing and health professions, behavioural sciences, basic sciences, and humanities and technologies (OvidSP, 2014). Additionally, a number of journals were identified for each discipline as a secondary, complementary source to ensure that relevant articles were not missed (Table 1).

To identify the literature covering the overlap of the three disciplines (built environment, pedagogy and PA/SB), four 'themes' were identified (Figure 1) and employed for both the OvidSP database search and the discipline-specific journal search: built environment and physical activity (BE_PA), built environment and pedagogy (BE_PED), physical activity and pedagogy (PA_PED), and built environment, physical activity and pedagogy (BE_PA_PED). Note that the PA themes also include SB.

Table 1 Discipline-specific journals used to identify papers

Disciplines	Journals
Built environment	*Health and Places*, *Journal of Environmental Psychology*, *Environment and Behavior*, *Indoor and Built Environment*, *Building Research & Information*, *Journal of Environmental Education*, *Journal of Occupation Science*, and *Intelligent Building International*
Physical activity	*International Journal of Behavioral Nutrition and Physical Activity*, *Pediatrics*, and *Journal of Physical Activity and Health*
Pedagogy	*Cambridge Journal of Education*, *Oxford Review of Education*, *British Journal of Education Studies*, *Education 3–13*, and *International Journal of Early Years Education and Pedagogies*

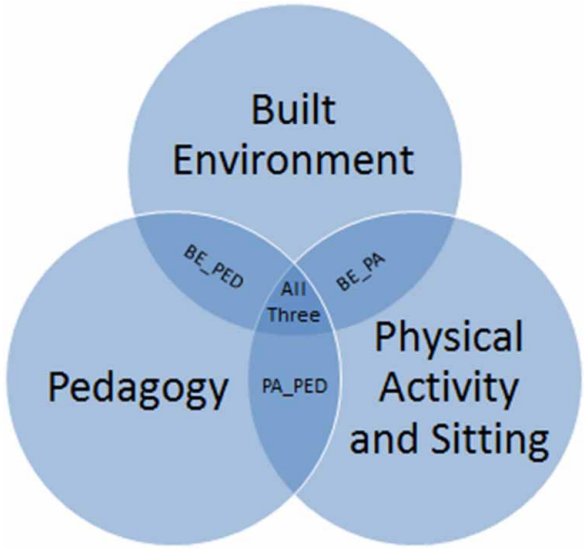

Figure 1 Identification of the research themes

Preliminary search results

The search involved a preliminary identification of papers, both in OvidSP and in the journals, followed by an initial pruning primarily based on assessing the papers' titles. Searches were performed with keyword combinations covering the four themes. A total of 4818 articles were initially identified: 2445 articles in BE_PA from 16 search combinations; 204 articles in BE_PED from 14 search combinations; 1960 articles in PA_PED from 17 search combinations; and 209 articles in BE_PA_PED from 29 search combinations. After an initial title-based assessment was carried out to remove articles that were not deemed relevant, a total of 639 papers were identified to be further assessed for inclusion in the study (Table 2).

A separate keyword search covering built environment, PA and pedagogy was employed on each disciplinary journal, generating a total of 3979 papers to which an initial title-based pruning was applied, resulting in 85 articles selected for further assessment. These 85 papers were cross-referenced with the 639 OvidSP results and it was found that only two records were a repeat, hence overall a total of 83 papers (Table 3) from the journal searches were brought forward to the next assessment stage.

Refinement of search criteria and selection of papers for review

The previous stage identified a total of 722 papers (639 + 83) generated via OvidSP and journal searches.

Table 2 Initial OvidSP search results and preliminary selection (based on an assessment of papers' titles) of papers for further assessment

Theme	Initial search results	Selection after preliminary assessment
BE_PA	2445	262
BE_PED	204	50
PA_PED	1960	286
BE_PA_PED	209	41
Total	4818	639

Table 3 Initial journal search results and preliminary selection (based on an assessment of papers' titles) of papers for further assessment

Theme	Initial search results	Selection after preliminary assessment
Built environment journals	2490	78
PA/SB journals	857	1
Pedagogy journals	632	4
Total	3979	83

Table 4 Abstracts selected for inclusion in the final review

Theme	Selected for inclusion[a]
BE_PA	14 (6)
BE_PED	37
PA_PED	19 (15)
BE_PA_PED	0
Total	70 (58)

Note: Some abstracts were lacking some key descriptions and required a review of the whole paper. This resulted in the subsequent exclusion of a small number of papers. The final numbers selected are shown in parentheses.

These papers were further assessed for inclusion in this review. For each of the themes (Figure 1) relevant academics evaluated the abstracts (first independently and then together) and selected those deemed most relevant. As recommended by Levac et al. (2010), this was an iterative process whose purpose was also to refine the study selection criteria, following practical considerations alongside disciplinary and methodological ones. Given the large amount of literature available on PE, MVPA and school playgrounds, and considering that the main focus of this review is primarily PA/SB during class and breaks, the team agreed to add further exclusion criteria: play, playground, outside education and field trips. This also gave the opportunity to define more fully those aspects of the school built environment and PA/SB under consideration. Hence, the school built environment was defined as:

> Aspects of the built indoor environment within the school boundaries, excluding those solely dedicated to play or physical education. This includes the building (e.g. structure, envelope, interior layout etc); the furniture (fixed and not) and fixtures such as artwork and fixed blackboards; but excludes playgrounds and any play-related equipment/facilities, and ICT [information and communication technology] equipment.

For PA/SB, the selected focus was on specific aspects of PA and SB, namely:

> any walking occurring as a result of pupils moving to/from destinations within the indoor school environment; sitting, standing and 'moving around' within the classroom environment or any other indoor space within the school besides those explicitly/solely dedicated to play or physical education.

Table 4 summarizes the final number of articles selected for review. No studies were found that explicitly addressed all three aspects – built environment, PA/SB and pedagogy – as defined in the inclusion/exclusion criteria and relevant definitions.

The next section discusses the results of the abstracts' review by theme. When reviewing the abstracts, the main aim was to map existing knowledge and thus identify knowledge gaps, as opposed to assessing quality or extracting data. Table 5 systematically maps relevant aspects of each study on the links between PA/SB and pedagogy and the built environment.[2] Note that in many cases the abstracts did not cover all the relevant information (*e.g.* in some cases it was unclear if the term 'environment' referred to the built environment's aspects) and hence a scan of the full paper was required.

Pedagogy and the indoor built environment

Research literature on the relationship between the indoor built environment and pedagogy is concentrated largely in built environment publications and in journals devoted to environmental psychology and behaviour. There is little in education or social science journals (journals where one would expect a focus on pedagogy) concerned with this relationship.

Table 5 Overview of key aspects of the reviewed studies on the links between physical activity/sedentary behaviour and pedagogy or the built environment

Reference	Country	Study type	Age or school type	Overall study objective	Relevant measure	Relevant outcome	Relevant finding
Physical activity/sedentary behaviour and pedagogy							
Brandstetter et al. (2012)	Germany	Intervention study	Second grade	Impact of integrating two short daily exercise blocks into the curriculum with additional focus on television viewing and soft drink consumption	BMI, waist circumference and skin-fold thickness	BMI	No difference on BMI, waist circumference and skin-fold thickness
Darian (2012)	US	Intervention study	Kindergarten–third grade	Impact of programme promoting PA-integrated lessons	Physical and academic development, teacher-led movements and using movement to aid cognitive learning and prepare for sedentary work and focus/attention	Eagerness to participate, recall, focus and pay attention	Increased eagerness to participate, recall, extending focus and pay attention
DuBose et al. (2008)	US	Randomized control intervention study	Elementary	Protocol of a three-year programme of PA-integrated lessons compared with traditional lessons	BMI	BMI	After two years 21 of 22 schools remain in the study
Finn et al. (2011)	US	Intervention study	Fifth–sixth grade	Feasibility of integrating PA into the science curriculum over eight lessons	Digital monitoring of heart rate, calories and light PA, qualitative assessment of interest/engagement and classroom time management	Light PA, interest/engagement and classroom time management	Digital monitoring devices were used as an engaging way to increase school-based PA effectively
Goffreda (2011)	US	Intervention study	K12	Impact of classroom-based PA programme	School-based steps, behavioural outcomes, literacy and mathematic skills	School-based PA, behaviour and academic outcomes	Increased school-based steps and associated with positive behavioural outcomes. No effect on literacy or mathematic skills
Grieco, Jowers, and Bartholomew (2009)	US	Intervention study	Elementary	Impact of PA-integrated lessons compared with traditional lessons	Directly observed momentary time sampling of time on-task from before to after the lesson	Time on-task	Time on-task decreased for traditional lessons, with a greater decrease in overweight students. Time-on task remained the same for PA-integrated lessons
Hammett (2009)	US	Controlled intervention study	Kindergarten–first grade	Impact of a 10-week programme of PA-integrated read-aloud sessions compared with control	Acquisition of targeted vocabulary words	Vocabulary acquisition	Increased gains in vocabulary and student preference for read-aloud sessions

(*Table continues*)

Table 5 Continued

Reference	Country	Study type	Age or school type	Overall study objective	Relevant measure	Relevant outcome	Relevant finding
Llargués et al. (2012)	Spain	Randomized control intervention study	Primary	Impact of a four-year programme promoting healthy diets and increasing PA through educational pedagogy	Overweight and obesity over four years	BMI	Larger increases in the prevalence of both overweight and obesity in the control group. Differences were maintained over time
Lucht and Heidig (2013)	Germany	Controlled intervention study	Elementary	Impact of a digital game combining playing, learning and PA compared with teacher-centred lessons	Memory and spelling of new vocabulary and attitudes towards English	Acquisition of factual knowledge and attitudes towards English as a second language	Memory and spelling of a new vocabulary did not increase. Attitudes were improved
Okely, Hardy, Pearson, McKeen, and Batterham (2012)	Australia	Controlled intervention study	Primary	Feasibility and efficacy of a three-year programme to target and structure physical education, modifying the physical and social environment and developing links with home and the local community compared with the control	Cardiorespiratory endurance and BMI	Cardiorespiratory endurance and BMI	Small but non-significant increase in cardiorespiratory endurance and a decrease in BMI
Schetzina et al. (2009)	US	Intervention study		Impact of a programme promoting healthy eating and PA	Nutrition offerings, PA, acceptability and implementation	Nutrition, PA, implementation, effectiveness, feasibility and sustainability	Improved nutrition offerings and increased PA during the school day. The programme was acceptable, successfully implemented and sustained
Vanhelst, Beghin, Fardy, Bui-Xuan, and Mikulovic (2012)	France	Intervention study	7–17 years	Impact of a one-year programme on PA and health education in obese students	BMI, classroom behaviour and academic performance	BMI, classroom behaviour and academic performance	Decreased BMI and improved academic performance. Interactions between BMI and academic performance and classroom behaviour
Vazou, Gavrilou, Mamalaki, Papanastasiou, and Sioumala (2012)	Greece	Intervention study	Sixth grade	Impact of a programme of PA-integrated lessons compared with traditional lessons over six lessons	Intrinsic motivation inventory to assess interest/enjoyment, perceived competence, effort, perceived value of the lesson and pressure	Academic motivation	Interest/enjoyment, perceived competence and effort increased. There were no differences in the perceived value of the lesson and pressure

(*Table continues*)

Whitt-Glover, Ham, and Yancey (2011)	US	Randomized control intervention study	Elementary second–fifth grade	Impact of a 10-minute PA breaks in classrooms compared with control	Directly observed PA	Classroom-based PA and on-task behaviour	Increased light and moderate PA and time spent in on-task behaviour
Physical activity/sedentary behaviour and the built environment							
Benden, Pickens, Shipp, Perry, and Schneider (2013)	Texas, US	Controlled intervention study	Second grade, elementary school	Assess the impact of a stand-biased workstation on posture and discomfort	Stand-biased workstations	Posture and discomfort	Stand-biased desks presented no additional ergonomic issues
Blake, Benden, and Wendel (2012)	Texas, US	Controlled quasi-experimental	First grade, elementary school	Pilot study of standing-height desks	Standing-height desks	Caloric expenditure	Standing-height desks increase caloric expenditure and the potential behavioural effects of standing
Cardon, De Clercq, De Bourdeaudhuij, and Breithecker (2004)	Germany	Intervention	Eight-year-old children	Assessing the sitting habits of 'moving' school' versus traditional school	'Moving school' (built environment details unclear)	Accelerometer data and ergonomic observations	Sitting habits are more favourable in a 'Moving school'
Hinckson et al. (2013)	Auckland, New Zealand	Controlled trial	Third and fourth grade, elementary school	Assess the acceptability, musculoskeletal discomfort and impact on SB/PA outcomes of standing workstations	Standing workstation	SB/PA outcomes, acceptability, musculoskeletal discomfort	Standing workstations can be successfully integrated in classroom environments and appear to decrease overall sedentariness
Kasali and Doğan (2010)	Turkey	Cross-sectional	Fifth, sixth and seventh grade, elementary school	Assessment of students' place preferences between indoor and outdoor non-classroom spaces during recess and their activity patterns in these spaces	Indoor and outdoor spaces	Percentage of location-specific activities based on self-reported preferences and observations	Students are aware of spatial features and make choices accordingly, preferring places that offer variety and largely to avoid congestion. Students are a good source of information for school designers
Lanningham-Foster et al. (2008)	US	Intervention	Fourth–fifth grade elementary	Impact on PA of activity-permissive classroom versus a traditional classroom and a classroom with desks encouraging standing	Activity-permissive specially designed classroom	Accelerometer data	Children will move more in an activity-permissive environment. Redesigning the school itself may be useful/needed

Note: BMI = body mass index; PA = physical activity; SB, sedentary behaviour.

Making Space: Architecture and Design for Children and Young People (2011), a publication by Children in Scotland, sets out several key themes that are taken up in other research literature. These include the flexibility and autonomy afforded to children and their teachers by well-designed spaces (Eviston et al., 2010; Parnell & Procter, 2011); the effect of light and space on learning and well-being; the effect of design on motivation (Hargreaves, 2004; Higgins, Hall, Wall, Woolner, & McCaughey, 2005); the importance of local environments for learning (Ernst, 2007); and the impact of the built environment on the imagination. The relationship between space and behaviour is fundamental to psychological studies in this area (Moore, 1986).

An emphasis on well-being of the learner is particularly evident in these papers. Studies concentrate on the moderation of noise annoyance in school environments (Boman & Enmarker, 2004); the positive impact of limited-visibility leafy environments for aiding concentration, attention, emotional states, behaviour, and personal health and well-being (Han, 2009); the positive impact of personalization of the immediate environment on behaviour performance and academic achievement (Maxwell & Chmielewski, 2008); an ecological understanding of the relationship between space and learning (Moore, 1986); and the effect on health and pupils' performance of specific environmental aspects of lighting (Winterbottom & Wilkins, 2009) and air quality (Chatzidiakou, Mumovic, & Dockrell, 2013).

Attributing outcomes such as cognitive advancement or academic performance of pupils to a causal relationship between the built environment and the outcome is notoriously tenuous. Generally, the current authors have avoided such claims, preferring to focus on the impact of the built environment on pedagogical dimensions of the built school and classroom environment. One example of a study that attempts to relate school design (and the condition of the building) to attendance and academic attainment is that by Durán-Narucki (2008, p. 278), who accepts that 'little is known about how the condition of school facilities affects academic outcomes'. There are more such studies on primary schools (ages 5–11) than on pre-school/kindergartens (ages 2–5) or secondary/high schools (ages 11–18). This may be the result of the more organic, integrated approach to the curriculum in primary schools and the emphasis on the learner rather than on the subject/discipline, thus leading to a consideration of the way the environment helps or hinders well-being and learning.

At pre-school level, Read, Sugawara, and Brandt (1999) investigated the changes that differentiated space (*e.g.* changes in ceiling height or wall colour) have on children's cooperative behaviour. Interpersonal relationships amongst children between 21 and 36 months were the focus of a study that looked at the deployment of furniture as obstacles or facilitators of peer relations (Legendre, 1999). It concluded that such arrangements did not facilitate better peer relations where the relations were already weak or poor, but did improve matters for those who already had good relations. They concluded that the immediate physical environment *enhances* rather than radically changes such relations. Kantrowitz and Evans (2004) noticed that the number of children engaged in activity areas had an impact on their well-being and motivation.

Studies on the relationship between the built environment and pedagogy in primary schools are numerous. Generally, they do not consider pedagogy *per se*, but rather assess the impact of the environment on well-being and attention. In case studies of six primary schools in Ireland, Darmody, Smith, and Doherty (2010) explored indoor space in relation to the use of new technologies, the relative size of classrooms and the schools themselves. Schools built to current design guidelines are seen more positively than older schools in terms of classroom size, accessibility, lighting, heating, ventilation and storage. Other studies covering these factors were reported by Barrett, Zhang, Moffat, and Kobbacy (2013) and Wall, Dockrell, and Peacey (2008). 'Ownership' of space by pupils results from the mounting of pupils' work as a permanent feature of the built environment (Killeen, Evans, & Danko, 2003). From the pupils' point of view, ownership reaches beyond the display of artwork to the actual learning spaces themselves, though not to 'hard' spaces like corridors and stairs (Barrett & Zhang, 2012; Barrett, Zhang, & Barrett, 2011). Maxwell and Chmielewski (2008) explored how young children's self-esteem is affected by the built environment, and found positive effects for first-graders on the two measures of self-esteem deployed, but that for kindergarten children the positive effect was seen in only one measure.

Secondary school studies are more concerned with multidisciplinarity. Gislason (2009) pointed out that a school with an environmental studies focus found its open-plan architecture complemented the teaching of the curriculum, as well as contributing to a more positive and productive social climate. However, Cotterell (1984) found that open-plan design at secondary level created more pupil and teacher anxiety, as there was more time devoted to transitions from one activity to another, and more off-task behaviour. In a multilevel analysis (Rowan, Raudenbush, & Kang, 1991), it was suggested that teachers from different subject as well as from different social backgrounds perceive the structures of schooling differently, including the physical structures of the built environment. These disparate studies in the built environment and secondary education suggest there is more work to be done particularly in the wake of the *Making Space* report by Children in Scotland (2011) on school design and learning.

Across all school levels, there is a small body of research literature on the impact of the built environment on children with learning difficulties. Studies of children who are partially or completely deaf (Martins & Gaudiot, 2012) and of those with a diagnosis of autism spectrum disorder (ASD) (McAllister & Maguire, 2012) are significant exceptions. The more general issue of inclusion or exclusion from mainstream classes of children with learning difficulties (Holt, 2003) is important for building design, an issue also explored by Pivik (2010).

Physical activity, sedentary behaviour and pedagogy

Of the 19 papers on this topic first identified through title and abstract review (Table 4), four were excluded after reviewing the full text (necessary owing to incomplete information in the abstract). Of the 15 remaining papers that were included, 14 were intervention studies and one was an informational book providing guidance on how to incorporate movement in teaching. Sample populations ranged from kindergarten to secondary school with most studies based in primary school populations. The majority of papers were peer-reviewed journal articles with one book (Lengel & Kuczala, 2010) and three dissertation theses (Darian, 2012; Goffedra, 2011; Hammett, 2009). Most studies were conducted in the United States (eight studies), with six conducted in Europe and one in Australia.

Most of the interventions explored the impact of integrating PA into classroom-based lessons by either incorporating short PA breaks into the lesson plan or using PA teaching techniques incorporated as a key component of the learning experience (*e.g.* using a hopscotch grid to map out vocabulary; Lucht & Heidig, 2013). This scoping review has identified some preliminary evidence that classroom-based PA is both feasible (Finn et al., 2011; Schetzina et al., 2009) and effective in increasing students' PA (Goffedra, 2011; Schetzina et al., 2009; Whitt-Glover et al., 2011). In addition, an on-going US-based study suggests that schools are supportive of such an initiative, as long-term retention of participating schools in the study was high (DuBose et al., 2008). Lengel and Kuczala's (2010) *The Kinesthetic Classroom* provides a general overview of techniques used for classroom-based PA and suggested that the practice has a positive influence on academic learning in addition to aiding classroom management and benefiting students' physical well-being. Other studies identified in the review also draw on these outcomes.

Four studies that investigated the effect of classroom-based PA on academic learning reported mixed results. Using PA as a teaching technique for language acquisition in primary school pupils was found to increase vocabulary learning in students exposed to the Active Read-Aloud Strategy intervention (Hammett, 2009), but there was no advantage of the 'hopscotch learning game' compared with traditional teacher-centred learning in Lucht and Heidig's (2013) study. Similarly, while incorporating PA into the school day had a positive effect on academic performance in students aged 7–17 years (Vanhelst et al., 2012), elsewhere it had no effect on mathematics and literacy skills in children attending kindergarten to secondary school (Goffedra, 2011). Mixed findings may be attributable partly to differences in intervention duration and the precise academic outcomes that were included, however more research is needed to draw reliable conclusions. Comprehensive reporting of intervention components (*e.g.* design, setting, compliance) will aid synthesis as the evidence base grows.

More consistent effects of classroom-based PA were found for behavioural outcomes, with more available research to support findings. Specifically, classroom-based PA was found to enhance classroom management and control, across ages (Goffedra, 2011; Lucht & Heidig, 2013; Vanhelst et al., 2012; Whitt-Glover et al., 2011) and increase students' attention and focus on the task – both when PA was used as a teaching tool and when it was incorporated into the lesson through short activity breaks (Grieco et al., 2009; Vazou et al., 2012; Whitt-Glover et al., 2011). Moreover, one study found that increases in attention and focus extended beyond the active period of the lesson, preparing the student for later, sedentary, academic working (Darian, 2012). Interestingly, Grieco et al. (2009) suggested that overweight primary school students benefitted preferentially from classroom-based PA compared with healthy weight students, perhaps paving the way for more research investigating the effects of tailored interventions. Finally, there was also preliminary quantitative and qualitative evidence that classroom-based PA was positively related to student motivation and interest in the academic subject and that students preferred PA-based teaching techniques (Darian, 2012; Hammett, 2009; Lucht & Heidig, 2013).

Several other studies related classroom PA to health-related outcomes demonstrating mixed effects. One study with data from 945 children showed that embedding a weight change intervention into the curriculum had no effect on body mass index (BMI), but showed a reduction in waist circumference (Brandstetter et al., 2012). Another study showed a favourable effect on BMI in the intervention group in a four-year trial of an educational pedagogy PA and lifestyle programme (Llargués et al., 2012). Increasing school-time PA led to no differences in cardiovascular health and a mixed effect on BMI in other studies (Okely et al., 2012; Vanhelst et al., 2012).

There was a gap in research examining SB and pedagogy. Although several papers noted that children sit too much, studies generally sought an increase in PA rather than a reduction in SB. Additionally, there were no observational studies.

Physical activity, sedentary behaviour and the indoor built environment

For this theme, originally 14 papers arising from the initial searches (Table 4) and six papers derived from references within relevant papers were selected for review. However, in many cases it was not clear from the abstract whether terms such as 'environment' referred to physical environments or whether terms such as 'physical' or 'built' environment included aspects of the indoor built environment not solely or mainly dedicated to PE (and/or MVPA). Hence in most cases the full paper was screened to assess whether it met our definitions and inclusion criteria. After this screening process, six papers were found to be relevant and one paper (Harrison & Jones, 2012) was considered more suitable for the Introduction section as it contained a review and conceptual framework of those school-level built environment factors excluded through our criteria.

Of the six papers, three were intervention studies investigating standing-height desks within primary schools, in terms of their acceptability, and impacts on SB, musculoskeletal discomfort, posture and calorie expenditure. A controlled trial in two primary schools in Auckland, New Zealand, with participants from the third and fourth grades found that children and staff members were respectively happy with and supportive of the standing workstations (Hinckson et al., 2013). Children in the intervention group sat less, stood longer and engaged in fewer transitions from sitting to standing compared with the control group. The study concluded that 'standing workstations can be successfully integrated in classroom environments and appear to decrease overall sedentariness' (Hinckson et al., 2013, abst.). A quasi-experimental pilot study of standing-height desks was conducted in five first-grade classrooms in a Texas primary school, with two control classrooms, two treatment classrooms and one classroom that was a control in the fall term and treatment in the spring (to allow within-group comparisons). The intervention proved to be effective in significantly increasing caloric expenditure (Blake et al., 2012). Another paper more specifically focused on the assessment of time spent in suboptimal postures and self-reported discomfort of students during the use of traditional seated and stand-biased desks. The posture of 42 primary school students was assessed as they worked at their desks that included 15 standing types and 27 seated types. Student body part discomfort surveys were also used to assess discomfort of students. No significant difference was found between the two groups and time spent in non-preferred postures and body discomfort, however children using stand-biased workstations reported less discomfort overall (Benden et al., 2013). The paper highlighted that 'a study containing a larger sample and older children that includes postural observation throughout the school day is needed' (Benden et al., 2013, abst.).

A study in Turkey investigated fifth-, sixth- and seventh-grade students in three private primary schools to understand their place preferences between indoor and outdoor non-classroom spaces during recess and their activity patterns in these spaces. The study concluded that 'students are good sources of information in the design and planning of the environments they occupy' (Kasali & Doğan, 2010, 518). Whilst the study did ask questions pertaining to activities relevant to PA and SB (*e.g.* sit, wander around, etc.), it is not immediately clear how the data can be interpreted with respect to the impact of built environment features on PA and SB.

The remaining two studies examined the impact on PA and SB of an activity-permissive classroom environment for primary school children. A US-based study tested the hypothesis that primary school-age children will be more physically active while attending school in a novel, activity-permissive school environment compared with a traditional school environment (Lanningham-Foster et al., 2008). The students attended school in three different environments: a traditional school with chairs and desks, an activity-permissive environment and, finally, their traditional school with desks that encouraged standing. The activity-permissive environment was designed specifically to encourage an active learning environment. The actual 'classroom' was a plasticized hockey rink which also included

> standing desks and vertical, mobile whiteboards, [. . .] miniature golf, basketball hoops, indoor soccer, climbing mazes, and activity promoting games. The children used wireless laptop computers and portable video display units to facilitate mobile learning

and children were allowed to move around during lessons (Lanningham-Foster et al., 2008, p. 1850). Accelerometer data from the school children were compared with another group of age-matched children whose PA was monitored during summer vacation. On average the children attending school in the activity-permissive environment moved significantly more (mean $\pm$ SD = 115 $\pm$ 3 m/s^2) compared with those in either the traditional environment (71 $\pm$ 0.4 m/s) or in the traditional school with standing desks (71 $\pm$ 0.7 m/s^2). The children in the activity-

permissive environment were as active as children on summer vacation. The study concluded that 'children will move more in an activity-permissive environment' and that 'strategies to increase the activity of school children may involve re-designing the school itself' (Lanningham-Foster et al., 2008, abst.). A study in Germany evaluated differences in classroom sitting habits of eight-year-old children between the 'Moving school' and a traditional school. Twenty-two children involved in the project for 1.5 years were compared with 25 children in a traditional school (Cardon et al., 2004). The study found that children from a traditional school spent an average of 97% of the lesson time sitting statically, whilst for those in the 'Moving school' this posture was replaced by dynamic sitting (53% of the lesson time), standing (31%) and walking around (10%). Higher levels of PA during lessons were recorded via accelerometer data within the 'Moving school', and overall results showed that sitting habits are better in a 'Moving school', with no differences in self-reported back or neck pain between the two groups. It should be highlighted that the focus of the study was primarily on 'healthy backs' and posture rather than explicitly on PA or SB. Unfortunately the paper does not provide detailed information on built environment aspects of the 'Moving school' concept, although it does mention, for example, that the classroom was equipped with ergonomic furniture. However, there is also a reference to 'behavioural influences' in the 'Moving school' concept, therefore it is unclear to what extent the effects observed in the study can be attributed, solely or partly, to built environment aspects.

Discussion

This study adopted a scoping review approach to identify evidence and knowledge gaps on the links between aspects of the indoor school built environment, PA and SB of children at school, and pedagogy. The review identified a few studies, especially in the primary schools settings, but found an overall lack of research addressing all three aspects.

Given the wide-ranging nature of the research question, a balance had to be found between comprehensiveness and depth, which was translated into the inclusion/exclusion criteria and search terms. As pointed out by Levac et al. (2010), the iterative nature of the selection process must be highlighted, whereby additional exclusion criteria were added mid-process, *e.g.* to exclude outdoor school environments and play or PE. This reduced the number of abstracts for review to a manageable level while ensuring a more precise focus that was in line with the original emphasis on indoor environments, and on aspects of PA/SB not solely or mainly aimed at MVPA. Following the addition of further exclusion criteria, no changes were made to the keywords utilized for the searches, since these were considered sufficiently broad to capture the phenomena we wished to investigate. However, it is possible that some specific search terms might have revealed relevant studies, although a preliminary investigation of the keyword 'furniture', for example, did not provide such additional results. On the other hand, search terms such as 'posture' and 'ergonomics' might have produced further results, although the link with PA/SB may have not been very clear. Given the prominence of play-focused activities in the pre-school setting, the exclusion of 'play' might have affected the results. However, it should also be mentioned that our conceptualization of 'play' did not exclude classroom-related activities. On the other hand, whilst this study aimed to cover break times (at least those taking place indoors), the exclusion of 'play' may have excluded relevant studies. This may be considered a limitation, dictated by the need to strike a balance between comprehensiveness and focus, but it also ensured a greater emphasis on aspects that are otherwise often overlooked.

This review mainly aimed to identify knowledge gaps as opposed to assessing publications' quality or extract data, and hence the study's main focus on abstracts – which guaranteed a wide-ranging scope – was considered suitable to this aim. Nonetheless, it is possible that a screening of full papers may have highlighted additional results or more nuanced issues, and in this sense a focus on abstracts may be a limitation. However, it should be highlighted that on several occasions full papers were screened to assess their suitability and/or capture some aspects that were not clear in the abstract – thus ensuring a suitable degree of clarity in the review process.

Given the heterogeneity of the three disciplinary fields involved, the selection of suitable search terms applicable across these disciplines can be problematic. For example, whilst in lay terms 'physical activity' may be intended as synonymous of 'movement' or 'lack of inactivity', within a specific research field the term is often used as synonymous of MVPA – thus mainly pertaining to PE and breaks in the school setting. On the other hand, terms such as 'physical environment' or 'built environment' – which conceptually can encompass a large variety of factors – are often used as 'umbrella terms' while actually referring only to a specific aspect of the built environment. For example, Bassett et al. (2013) carried out a study that aimed to 'quantify the increase in energy expenditure associated with school-based policies and built environment changes' (Bassett et al., 2013, abst.). However, for built environment changes pertaining the school grounds (as opposed to neighbourhood-level aspects), the study solely focused on modifications to the playgrounds. The study did not provide a clear framework or explanation for this specific interpretation of the

school built environment, although presumably this is partly due to availability of suitable studies. It is also worthwhile reporting here the study's conclusions:

> of the various policies and built environment changes examined, the largest effects were seen with mandatory PE, classroom activity breaks, and active commuting to school.
>
> (Bassett et al., 2013, abst.)

'Modified playgrounds', for example, resulted in additional six average minutes of MVPA gained per school day, whilst 'mandatory PE' resulted in 23 minutes and 'classroom activity breaks' in 19 minutes. The paper highlighted that whilst changes to the built environment might not result in large PA or metabolic gains, they could still form part of a multifaceted strategy aimed at increasing PA levels and reducing SB throughout the school day.

The heterogeneity of the research fields underpinning the research question also meant that whilst OvidSP – a widely used search platform – was utilized as the primary information source, a parallel search of discipline-specific journals revealed several additional papers. This highlights the methodological difficulties associated with such broad multidisciplinary questions and suggests that further studies may need to use more than one search platform. The strength of the OvidSP database is its depth. Applying a generic search such as built environment or PA yields over 300 000 results in Ovid whilst the same search in 'Environment and Behaviour' yields 247. A more specific search such as built environment and PA yields 2947 results in Ovid. In 'Environment and Behaviour', this drops to 48. For practical reason, Ovid is more suitable to use specific keywords with more variations whilst discipline specific journals yielding much less results are more suitable with generic search terms. An example is the article entitled 'Impact of space and color in the physical environment on preschool children's cooperative behavior' (Read et al., 1999). It can be found in 'Environment and Behaviour' using the basic keywords combination of school and learning that yields 214 results. In Ovid 530 540 results were identified.

With respect to the topic investigated here, it must be emphasized that the research question could be usefully framed in terms of its what/where/when aspects. Overall the review revealed that many studies were not particularly clear about the '*what*' aspects (*i.e.* which levels of PA and/or aspects of SB), nor explicitly identify *where* these do or should take place, *e.g.* in the playground or classroom, or *when* they occur whether during lessons and/or throughout a typical school day. This lack of clarity makes it difficult to form a comprehensive assessment of the PA/SB potentials of various factors within schools. With reference to the definitions of indoor school built environment and PA/SB utilized in this study, one needs to consider that the amount of walking between school destinations (in turn affected by their respective distance) is likely to be limited in pre-schools and possibly in primary schools, where children are generally neither permitted nor encouraged to move around the school. In some countries or school systems, secondary school children are mainly based in one classroom even at break times, while in others they change classroom according to the discipline of the lesson hence offering scope for accumulating light PA during classroom changes and breaks. In such cases the location and distribution of rooms, as well as the overall size of the school building, may be important however no research on this aspect was identified.

The 'triadic' nature of the topic investigated allowed an examination of studies addressing all three aspects (built environment, PA/SB, pedagogy) as well as studies investigating pairs of the three aspects. Whilst this had the advantage of framing the issue(s) in broad terms, it also resulted in very wide themes which we do not claim to have investigated exhaustively but rather to have addressed within the aims of our review and constraints of time and method. The theme 'Pedagogy and the indoor built environment', for example, is a very broad topic which could be the subject of a separate scoping review.

Conclusions

This review brought together a cross-disciplinary team of education, built environment and PA experts to carry out a scoping review of published abstracts in order to identify the impact of the indoor built environment on pedagogical approaches and levels of PA and SB of children during school times. The review included aspects of the indoor built environment not solely or mainly dedicated to PE and/or MVPA, with an aim to carry out a gap analysis of existing knowledge and point out further research needs within an emerging research field focusing on the potential for 'active design' features to impact positively on PA/SB, where pedagogical approaches also play an important role within the schools context.

The review highlighted that the indoor built environment is likely to impact on pedagogy and academic performance in a variety of ways, including the size of the school; the distance between buildings and classrooms; the pedagogic approach (active or passive); and the interior design of the classroom, as well as associated environmental parameters including indoor air quality, temperature, light and noise. Most studies on the links between PA and pedagogy have been carried out in primary schools, and focus on the impact of incorporating PA into classroom-based lessons. Such studies show that these approaches are generally

feasible and successful at increasing PA levels, although there is mixed evidence about their impact on academic performance. More consistent effects of classroom-based PA were found for behavioural outcomes (*e.g.* student attention and focus on the task), with more available research to support findings. Very limited research exists on SB and pedagogy.

A small number of studies were identified on the relationship in primary schools between PA/SB outcomes and aspects of the indoor school built environment not mainly or solely dedicated to PE or MVPA. A few intervention studies on standing-biased desks within primary schools point towards promising results in terms of their acceptability, impacts on PA/SB, musculoskeletal discomfort, posture and calorie expenditure – but further research is needed with larger sample sizes, longer timescales and inclusion of the impacts on academic performance. One intervention study was found suggesting that children will move more in an activity-permissive, specially designed environment and that strategies to increase the activity of school children may involve redesigning the school itself (Lanningham-Foster et al., 2008). However, it is debatable whether the specific design measures investigated in the study are repeatable on a larger scale.

Overall this review found a lack of studies explicitly addressing the interrelationships between the indoor school built environment, pedagogical approaches and/or academic performance, and PA and/or SB outcomes. Secondary schools are especially under-investigated. As for pre-schools, a lack of research is also apparent, although the exclusion of 'play' may have partly limited our identification of suitable studies on this school type. The review found a lack of comprehensive multidisciplinary understanding of what constitutes the 'school built environment'. We therefore suggest that a conceptual framework of the school built environment should be developed, mapping out its various aspects and identifying those elements of interest to different practitioners and researchers.

Given the solid evidence base that regular participation in PA and limited sitting are beneficial for children's health, and that PA levels in children are low while sitting time is high, more knowledge is needed on how the indoor school environment and pedagogy might interact and impact upon PA and SB of school children. Pre-school and secondary schools particularly need further study.

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Endnotes

[1]See www.take10.net/

[2]Papers on the built environment and pedagogy were considered too heterogeneous to be summarized into a useful table, hence Table 5 covers the paper in the BE_PA/SB and (PA_PED) themes.