2015

Exploring the use of new school buildings through post-occupancy evaluation and participatory action research

Andrea Wheeler
Iowa State University, andrea1@iastate.edu

Masoud Malekzadeh
Northampton University

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Abstract
This paper presents the results of the development and testing of an integrated post-occupancy evaluation (POE) approach for teachers, staff, pupils and community members using newly constructed school buildings. It focusses on three cases of UK secondary schools, demonstrating how users can be inspired to engage with the problems of school design and energy use awareness. The cases provided new insights into the engagement of school teachers, staff and young people regarding issues of sustainability, management, functional performance and comfort. The integrative approach adopted in these cases provided a more holistic understanding of these buildings' performance than could have been achieved by either observational or more traditional questionnaire-based methods. Moreover, the whole-school approach, involving children in POE, provided researchers with highly contextualised information about how a school is used, how to improve the quality of school experiences (both socially and educationally) and how the school community is contributing to the building's energy performance. These POE methods also provided unique opportunities for children to examine the social and cultural factors impeding the adoption of energy-conscious and sustainable behaviours.

Keywords
post-occupancy, school design, sustainable schools, energy performance, sustainable lifestyles

Disciplines
Architectural Engineering

Comments
This is an Accepted Manuscript of an article published by Taylor and Francis in *Architectural Engineering and Design Management* on March 13, 2015, available online: http://dx.doi.org/10.1080/17452007.2015.1021292.

Exploring the use of new school buildings through post-occupancy evaluation and participatory action research

Andrea Wheeler, *Department of Architecture, Iowa State University, Ames, IA, USA*
Masoud Malekzadeh, *Department of Architecture & 3D Design, Northampton University, Northampton, UK*

This paper presents the results of the development and testing of an integrated post-occupancy evaluation (POE) approach for teachers, staff, pupils and community members using newly constructed school buildings. It focuses on three cases of UK secondary schools, demonstrating how users can be inspired to engage with the problems of school design and energy use awareness. The cases provided new insights on the engagement of school teachers, staff and young people regarding issues of sustainability, management, functional performance and comfort. The integrative approach adopted in these cases provided a more holistic understanding of these buildings' performance than could have been achieved by either observational or more traditional questionnaire-based methods. Moreover, the whole-school approach, involving children in POE, provided researchers with highly contextualised information about how a school is used, how to improve the quality of school experiences (both socially and educationally) and how the school community is contributing to the building's energy performance. These POE methods also provided unique opportunities for children to examine the social and cultural factors impeding the adoption of energy-conscious and sustainable behaviours.

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Introduction

Many approaches to POE include participatory activities (Bordass & Leaman, 2005; Leaman & Bordass, 2001, 2010; Mallory-Hill, Preiser & Watson, 2010; Sanoff, 2001; Stevenson & Rijal, 2010; Watson, 2003, 2005; Watson & Thomson, 2005), and it is now common practice to engage stakeholder communities in interviews, walk-throughs, feedback and discussion of design solutions. Participatory action research (PAR), however, demands specific attention to how researchers engage with participants and firm commitment to principles of equality. There is now a general consensus that even the best buildings fail to perform as anticipated (Bordass & Leaman, 2012; Zimmerman & Martin, 2001). In response to tools such as LEED, regenerative design argues for the participation of building users in the complete design process and the co-evolution of human and natural systems in partnership (Cole, 2011). The issue of engaging stakeholders in the design process is particularly pressing in order to ensure design quality and good performance (including energy performance); however, integrated stakeholder engagement is still undervalued and there are few tools to assist in holistic evidence-based design (Cahill, 2007; Kindon and Pain, 2009; Payne, Mackrill, Cain, Strelitz & Gate, 2014; van Hoof et al., 2014). Furthermore, few have engaged with the question of inclusive participation in sustainable design (Kaatz, Root,

& Bowen, 2005). The POE, described in this paper, adopted PAR methods in the hope of eliciting otherwise hidden information about the occupants' relationship to the building. The primary aim of this research was to determine how the behaviours of different users contributed to the increase of energy use beyond what the designers had predicted. In the case of school buildings, effectively engaging children, as well as teachers and other staff, through PAR was essential because children's experience of space is different to adults and the great majority of school building users are children. A secondary aim was to investigate why modern buildings, designed for energy efficiency using modern simulation prediction tools, frequently fail to perform as intended informing design practices as well as to help simulation tool developers improve their products.

Cole, Robinson, Brown and O'Shea (2008) described a requirement within the POE process for "a programme for social engagement with a building system, providing space for inhabitants to express their understanding" (p. 330). Cole et al. (2008) emphasised the need for communication and dialogue with building occupants. Stevenson (2009, p. 128) concluded that it is desirable to have multiple methods of evaluation, as each building typology requires its own set of criteria. Stevenson (2008) suggested that one of the best approaches to POE is open questioning, which identifies hidden factors and tacit knowledge not revealed by structured questionnaires and can be especially revealing when the same participant is interviewed more than once. However, using this unstructured method with children raises some difficulties. For example, researchers have challenged the uncritical use of social-science methods, such as focus groups, with children as inappropriate (Vogel, 2009) and have argued for the development of tailored, "child-friendly" approaches. Researchers in the field of education tend to engage child participants with more art-based methods, which are less dependent on verbal or written communication skills (Hall et al., 2011).

The POE approach described in this paper focussed on need to transform people's relationships to their buildings and to the idea of sustainability, rather than relying simply on improvements in technology to achieve the desired reductions in energy consumption. This approach relates to the goals of PAR. The workshops held in the participating schools served two purposes: they obtained factual information about users' experience of the school that would be valuable to designers, and they also explored transformative ways of thinking and relating to the environment and to others.

The POE method developed in this project also aimed to provide a means of identifying social, cultural and economic considerations related to sustainability and of encouraging discussions that can motivate change. The perspective that "buildings don't use energy, people do" (Janda, 2011, p. 17) supports this focus on encouraging behaviour change. Janda argued that, through education focussed on addressing habits and social norms, we could dramatically improve the energy performance of buildings. Common design problems in new schools include poor acoustics, inefficient and poorly performing lighting strategies, inadequate ventilation and many spaces (such as halls and corridors) with no access to natural daylight (Commission for Architecture and the Built Environment, 2006, p. 32). Maintaining comfortable internal temperature and suitable air quality appear to be problems in even the

most contemporary new schools (Stringer, Dunne, & Boussabaine, 2012). School design can affect student behaviour, development, academic performance (Bakó-Biró, Clements-Croome, Kochhar, Awbi & Williams, 2012; Lackney, 2011) and health (Baker & Berstein, 2012). Occupants with day-to-day experience of these buildings can contribute to significant improvements in their performance.

New ideas about energy efficiency can be expected to emerge among the younger generation, as children are often quick to point out energy-wasting behaviours perpetrated by adults (Wheeler, Bouchlaghem & Malekzadeh, 2011, p. 70). Schools should seek to reinforce understandings of energy efficiency and renewable technologies, so as to support an emerging energy consciousness. A combination of humanities and social-science methodologies can foster reflection on energy use and sustainability issues, permitting the formation of new understandings of self and of our relationship to the natural world (Blewitt, 2004, p. 3). In this context, education is a means of recreating ourselves and our understanding of the world and others. Involving children in POE activities thus offers multiple potential benefits: it could provide designers with valuable performance data, user perceptions and new concepts to support sustainable design of school buildings, while also guiding both children and adults into fresh reflections on the deep problems of sustainability.

Background

As of 2003, a literature review identified more than 150 available POE analysis methods (Gaia Research, 2003). A guide to POE, developed by the Higher Education Funding Council for England (2006), also offered a summary of established methods. POE's primary benefit, according to these reviews, lies in its ability to collect valuable information that supports continuous improvement of architectural design. Our project was certainly concerned about collecting a wide range of information, but not just about energy performance of buildings, functionality and user comfort issues; we also wanted to probe motivating factors underlying behaviours that might be preventing the proper use of technology and the adoption of more sustainable lifestyles. The inclusion of marginalised users of buildings, such as facility managers, administrative staff and catering staff as well as children, aimed to uncover some of the hidden uses and misuses of the buildings.

The goal of PAR is not only to discover and describe problems and realities, but to change them. It starts with the understanding that people, including children, hold deep knowledge about their lives and experiences (Askins & Pain, 2011). In addition this project sought to understand relationships within the school community and with the new school building and its technology. The diversity and range of young people's experiences is rarely taken seriously, and very little is known about children's everyday experience of the built environment of schools (Holloway & Valentine, 2005; Upitis, 2004), especially the more energy-efficient and sustainable new facilities (Barratt-Hacking, Barratt, & Scott, 2007).

Methods

Research was conducted at three schools, with the construction companies who had erected the buildings participating by providing construction documentation and current performance. These companies permitted access to online performance data on energy use being collected at each school. These data were evaluated before the school visits and were discussed briefly by telephone with the facility managers. The three schools were chosen from a wider set of recently constructed schools due to the interest shown by the head teacher or building manager in the research program. Each school had opened within the previous three years. The researchers interviewed the head teachers at each school about their experience of the school design process and their perspectives on the successes or failures of the new school building; permission was then sought to hold a series of workshops with pupils and to interview other staff. At each school, six pupils (three girls and three boys from various classes) were selected to represent each grade from Year 7 (age 11-12) to Sixth Form (age 16-18), resulting in the involvement of about 140 students across the three schools. Pupils were invited to participate by their teachers. Workshops were scheduled during the spring term, meeting one hour per week over a four-week period, always at the same time of day so as to correspond to a regular class time and in the same room in the school. Some flexibility was permitted with regard to starting times in order to accommodate teachers' schedules, and to encourage their continued cooperation with academic study.

Table 1 summarizes the methods adopted, the literature reviewed and the theoretical background for each method. In each activity, researchers were particularly sensitive to any inhibitions that the children might experience due to the perceived power of the adult researchers. Researchers reassured participants that their views and opinions would not be shared with teachers and that they would not be identified by name in research papers or presentations.

Open discussion was used with children at the beginning of the series of workshops as a means of establishing relationships both with the researchers and amongst the children in the group. It also aimed to establish a habit of discussion so that children would engage willingly in group discussions during later activities. Inviting the children to tell stories allowed them to introduce the researchers to the school community—its ideas, beliefs and history. It permitted trust and dialogue to develop and encouraged children to enter with some creativity into explaining both failures and successes of the new school. Storytelling is a commonly used qualitative research method in health care (Koch, 1998), sociology (Cox & Albert, 2003), psychology, criminology (Garbarino, 1989) and linguistics; Pahl (2002, 2003) has used storytelling to elicit families' feelings about their homes.

Broad prompts were used with the children at this initial stage. A common starting question was simply "How do you like your new school?" The participants were not asked explicitly to tell stories; rather, the stories emerged as a result of participant engagement.

Table 1. Research methods considered and selected

Method	Accepted or rejected	Comments
Questionnaire	x	Not appropriate for working with children unless made "child-friendly", which would oversimplify the information that could be collected.
Measurement-based monitoring	√	Monitoring was carried out by the construction companies that had built the schools, and researchers had access to these raw data.
Review of historical records of the building	√	Researchers had access to some information from architects and the construction companies.
Interview	√	Interviews were carried out with adults, but considered inappropriate for child participants (Garbarino & Stott, 1989; Vogel, 2009).
Open discussion	√	Open discussion was adopted to encourage discussion of the school experience in ways that researchers could not anticipate and to elicit information on design use, school ethos and community values (Sanoff, 2001).
Video walk-through (Watson & Thomson, 2005)	√	This method was used not only to engage children but also to capture the more hidden experiences of building users in voice and image; it is supported by the video-ethnographic theories of Pink (2007, 2009).
Energy quiz	√	Adapted from a questionnaire designed for adults to determine attitudes towards energy demand reduction (Gill, Tierney, Pegg & Allan, 2010). The questions were simplified slightly and children were encouraged to discuss their answers in addition to providing an "I agree" or "I disagree" response.
Individual drawings/list making	√	This approach can work with all ages; younger children were asked to draw imaginary designs, while older children made lists of potential improvements.
Large-group "negotiated" and democratic design solutions	√	This approach (Biesta, 2009; Huckle, 2010) allowed children to think about sharing, apply democratic approaches to designing and engage in critical thinking.

The walk-through took place during the second week, following an approach described by Watson and Thomson (2005). Using a video camera, children showed researchers the places within the school that they liked and disliked and described how well or poorly they functioned. The walk-through offered pupils a way to express their views creatively and permitted observation of their experience, which they illustrated by reference to objects, building components or technologies. Researchers encouraged use of the video recorder and allowed pupils either to provide an ongoing commentary on the locations filmed or to create a documentary. The pupils themselves devised the route around the school and selected the places to visit.

To examine the influence of attitudes and values on energy behaviours, and also to gain some insight into the school culture regarding energy behaviours, researchers devised a modified quiz and administered it to all age groups, usually during the third session. The quiz was adapted from a questionnaire devised by Gill, Tierney, Pegg and Allan (2010). Whilst it provided an insight into some energy behaviours, the amount of prompting required by researchers to elicit answers from the students demonstrated the value of using more art-based and participatory methods of research with children. Sixth-formers responded best to the quiz, but none of the children showed much interest in it, and it was eventually abandoned as a research method.

Visual research methods were also adopted, asking children to draw positive and negative aspects of the school day and the building. This activity took place during the final week. Children not inclined toward drawing were asked to prepare lists. The use of visual research methods helped to elicit experiential (i.e. perceptual or emotional) knowledge that is located in the children's imagination but can be difficult to express linguistically. Especially for younger children, drawing and design activities were often an easier form of expression than conversing with adults, although many of the older students were happy to discuss their views and to engage in dialogue. Figure 1 displays examples of a drawing and a list from Year 7 students. The designs shown are illustrative of the pupils' views with regard to "what I think would be the best sort of place for me to learn". This activity allowed younger children to express their desires. As they did so, they often made direct references to such concerns as lack of access to computers or to the playing field, or the problem of a too-warm room containing the school computers – issues also identified in conversations with older children.

The large-group drawing was a natural progression from pupils' individual drawings. This choice of method was influenced by PAR theory and by Nold's (2009) "emotional cartographies". It gave children an opportunity to work together, discuss ideas and work toward democratically determined solutions for school improvement, with the researchers serving as facilitators. The dialogue that emerged from these sessions revealed much about the children's experiences in school and about the value that they placed on questions of social space, learning technologies and school rules, as well as permitting further expression of creative ideas followed by consensus building.

Results

School 1 was a mainstream school that shared its site with a special school. This unusual partnership was strongly supported by the head of the special school, which was rated outstanding on all dimensions of teaching and learning. The mainstream school, however, had not received a similarly glowing report from school inspectors; on the contrary, its performance was rated as unacceptable and teachers were working to improve educational standards. The school was built as part of the Private Finance Initiative (PFI), a scheme launched in the UK in 1992 to open up opportunities for private-sector involvement in the provision and modernisation of public services including schools and hospitals (House of Commons, 2011). Under PFI, the public sector procures both construction and maintenance services instead of procuring a capital asset and then operating the facility itself. The developer provides maintenance services for the duration of an agreed-upon contract (Davis & Ghani, 2006).

The mainstream school was an average-sized secondary school of around 1,000 students and the proportion of students known to be eligible for free school meals was in line with the national average (Birmingham City Council, 2011). The great majority of students were white and of British heritage; according to the Ofstead report (2010), the proportion of students from minority ethnic heritages was below average. The schools had moved into their new buildings in January 2009; the mainstream school had been assessed as falling below standards following its 2008 inspection. The present head teacher was appointed before the move, following a long and turbulent period of

instability (with seven different temporary head teachers). This change in leadership made it difficult for the researchers to assess the school's involvement during the design stages or the effectiveness of community participation in the design process.

The head of the special school provided the most insight on the design process and described her own strong involvement with the architects. She described inclusion as the guiding philosophy and the need to collocate the schools as one of the most important design concerns. For her, the collocation provided opportunities for integration, which she saw as the future of both mainstream and special education. Even the colours, she pointed out, were the same in both schools. However, despite the special school head's ambitions regarding inclusion, each school had its own distinctive culture.

School 2 opened its doors to students in January 2009 with a "very good" BREEAM rating. Despite being a Private Finance Initiative (PFI) school built by the same construction company as School 1, it was of a notably different character. School 2 depended heavily on rules and regulations, especially regarding the prevention of vandalism and other damage to the building. Relationships between students appeared less respectful and teachers' ability to manage conflict between students less effective. We were told of so-called "school riots" in response to orders communicated by teachers over a speaker system. Children also complained about the school design, calling it "prison-like", as illustrated by the practice of locking students into the school compound. Moreover, there were separate entrances for visitors (in the front) and pupils (in the back). Students were prohibited from putting drawings on the walls, which appeared bare and institutional; some students described the school as resembling a hospital. Most of these rules, according to both children and teaching staff, were driven by fears of vandalism and the financial penalties imposed by the construction company through their maintenance service for any damage to the building.

The building manager who had contributed to planning the school and participated in the original meetings with the architects stated in an interview that, in retrospect, his advice for designers was to pay more attention to the social spaces of schools, that is, to what children did when they were not in classrooms. As he put it, "I would have made the social area central to the design." This problem of poorly used social space extended to the staff. A large staff room went unused at lunchtime, as the teachers remained in separate resource areas associated with each department; only bribes of free coffee, tea and toast brought staff together at break time.

The students in this school had many complaints—about earwigs and beetles in the kitchen and dining room, smelly drains and the "school riots". The smell was later explained as caused by grease from the kitchen blocking the drains, but the lack of understanding about what was causing it, amongst teachers and students alike, led to the development of some creative narratives. Not all the responses were negative, however. The sixth-formers told us that the new school was nicer and warmer than its predecessor and did not let the rain in. One pupil stated:

> It is quite a big space, but there are a few issues, like the plaster coming off the wall over there, a big crack in the wall over there … it does get

> very messy because there aren't a lot of chairs and people have to wander around and hope for the best to find a seat at lunchtime. A lot of mess gets left down here … we had a riot and chairs got thrown around, and bins and such like.

School 3 was designed by an architectural practice, rather than the architectural department of a construction company, and built by a different construction company from the first two. The most dramatic story that emerged at this school was about the road crossing being in an improper place outside the building; the crossing was described as "an accident waiting to happen". Despite this traffic management issue, School 3 had the most striking architecture and gave the impression of being highly successful and not overly rule-bound.

The school opened its new facility in September 2009 and the Ofstead report in 2010 reported that its scores were rising. Published data placed the academy in the top 5% of schools nationally in student performance. Ofstead inspectors attributed the school's success to curriculum changes introduced before the move, including a broad range of curriculum pathways, a wide variety of vocational courses designed to match different needs, abilities and aspirations, and increasing standards.

The new secondary school replaced a set of old buildings. One of the initial driving educational objectives was the idea of a "school within a school". Whilst this idea was abandoned early within the design process, it still had an influence on the spatial arrangement of the facility. The school had been designed for 1,400 pupils and was slightly under-occupied at the time of the case study. Its front doors opened onto a large façade facing southwest toward an open countryside. The school's interior featured bold colours, which combined with the incoming daylight to create a very positive atmosphere. The building was organized with a central spine and radiating wings, each containing three storeys of teaching and learning spaces. Featured "break-out" spaces along the wings contributed to the maximum use of daylight. Great care was taken with regard to the circulation, the architects stated, to avoid long, potentially dark corridor spaces and places for bullying.

The spaces within the spine of the building serve a number of architectural purposes; some, such as the entrance hall and pupil dining space, are double-height. This arrangement maximises the sense of space and allows natural light deep into the building and into these social areas. The wings of the building create courtyard areas, one of which is designated specifically for the Year 7 pupils, to ease their transition into the student body. Bench radiators along the perimeter of the ground floor spaces also provide indoor gathering spots for pupils.

A certain degree of surveillance is provided by internal windows between "break-out" spaces or corridors and staff spaces, offices and the staff room. Toilets are always near staff rooms and not away from the main circulation area.

In terms of environmental systems strategies, the building is primarily mechanically ventilated, except for the assembly hall. Some spaces, such as the designated information and communication technologies (ICT) area and the laboratories, are air-conditioned. The sports hall has wind catchers and louvers, and the

dining room is naturally ventilated. The classrooms have localised ventilation units for heat recovery. According to the architects, considerable work went into making sure that these units were not too noisy, but the architects admitted that this goal had not been achieved. Moreover, pupils suggested that they contributed to overheating on hot days. Window strategy, according to the architects, was important in their approach to sustainability; passive design strategies were always the preferred approach. However, the main classroom windows could not be opened due to noise from a nearby motorway, as the architects could not otherwise meet regulations. These windows were of particular concern to the school community and a source of many discussions. In terms of the heating strategy, space heating was provided by perimeter radiators and there were four heating zones split between the wings of the buildings.

Maximising the use of daylight was an important theme for the architects, who argued that ample daylight offers benefits in terms of both educational performance and sustainability, as well as enhancing enjoyment and pleasure. The project architect made the following comments when interviewed:

> If there is anything we would like the children from [this school] to feel about the school, it would be to feel ownership of the school, to feel proud of the school, proud to go there—this is what sustainability is all about—if we can make the children feel that we respect them with the new school building they have, they will respect it, care for it and look after it. Making a building the children can love means a building they will look after.

This idea of ownership reappeared in conversations with the pupils but, unfortunately, not in a positive way; as in the other two cases, the PFI nature of the school was perceived by teachers and pupils alike as a barrier to this sense of ownership.

Analysis

We conducted a thorough content analysis of conversation transcripts and other meaningful information collected (Krippendorff, 2004, p. 18), encompassing the researchers' notes, interviews, and children's videos and drawings. Table 2 describes the main themes identified. In terms of energy use, children knew that lights were left on in the evening when the school was unoccupied, and that stairs and corridors had artificial lights unnecessarily turned on during daylight hours when these spaces were sufficiently lit. Whereas many of the architects' energy-efficient design strategies went unnoticed by children and adults alike, children were quick to point out wasteful energy behaviours and blame adults for them. As one Year 9 pupil complained, "They stand there in science and say you need to save energy and then I say, well, turn your lights off. … They are always telling us to save energy but why not them?" However, designers were also the focus of blame in some instances, such as the windows that were locked shut in School 3 to meet building regulations for noise.

If the leadership team could prove some fault in the school's design, they would have leverage to demand that the construction company make necessary changes at no charge. (In fact, this issue subsequently became the topic of a Freedom of Information

request submitted to the researchers by school staff.) Design issues were a significant problem for the perceived performance of School 3 as they led to prohibitions against the use of corridor spaces and break-out areas at lunchtimes and to toilets being closed for fear of vandalism.

For the children, the functionality of the dining space and lunchtime experience was the biggest concern in all three schools. The importance of social space and social experience emerged strongly throughout the workshops. Poor provision of lunchtime space for eating and for socializing was a significant issue. One of the factors contributing to this failure was teachers' inability to manage pupils' behaviour; this concern prevented the scheduling of staggered lunchtimes, which was the designers' original, space-saving intention at all three schools. The failure of design for social experience was not, however, simply limited to dining spaces but even included play areas. Encouraging dialogue with children brought to light ways in which children use the school building—as well as all sorts of ways in which they are prohibited from making proper and intended use of space. Here is one such comment:

> We like to sit under the stairs where there is carpet and a radiator, but we're not allowed. We just like to sit there because it is inside. We just like having a quieter area where you can sit and just be with your friends. … They should have little benches [outside that] people can sit on and a shelter in the winter. I know it is cold but I do like to go outside to get some fresh air. And also the lads when they play football would have somewhere for their bags. (Year 10 pupil, School 3)

The prohibition concerning space became a large part of many of the dialogues. For example, another pupil from School 3 stated:

> This is a very big area, the rooms are very big, and there is a lot of room for people to just wander up and down the corridors. Huge rooms, lots of big open spaces down here [but] this is the area [where] you are not allowed at lunchtime! You are not allowed up the stairs in the corridor at all. People have thrown things, the lights have been broken, there are lots of dents in the ceiling.

Many of the issues raised by pupils could be traced back to the relationship between each school and the PFI company that operated the facility. Teachers complained about the PFI arrangements; school managers cited prolonged administration processes to achieve simple maintenance tasks, along with excessive penalty costs imposed on them. The uncomfortable aspects of this relationship have had direct impact on students. One pupil described the school policy that prohibited the placement of drawings on classroom walls as like living in a rented house that you were not allowed to decorate. One school had just a single pair of bathrooms open for 1,300 pupils in order to prevent vandalism, the cost of which the school would have to bear—a cost described by the school

manager as three times what a local builder would charge. The PFI system's impact on facilities management means that making environmental adjustments can become a lengthy and overly complex procedure. Moreover, misunderstandings regarding building occupancy hours especially with increases evening hours activities and the anticipated usage of natural lighting and ventilation led to inaccurate assumptions at the design stage.

The difficulties involved in making energy predictions in school design are linked to the many assumptions that must be made during the design process, not all of which reflect real operational conditions. This is generally due to a lack of observational data on space usage in schools, especially new schools seeking to use more flexible or innovative space arrangements.

Interviews and workshops identified the following factors that were contributing to building performance below anticipated levels:

1. One school was primarily heated by an under-floor heating system. According to the records, the under-floor system had sustained some damage during building construction, causing a total failure of the system in one wing of the building. Since repairing the system was viewed as imposing a large initial cost and as potentially causing damage to other parts of the building, it was instead left unused in this wing of the building and the space was heated by perimeter radiators with thermostatic radiator valves.
2. In two schools, systems were installed to provide some of the hot water needed in the building through solar energy. However, the system was not operational in either school and there seemed to be no plans to repair them.
3. The primary users of the buildings (i.e. children and teachers) appeared to have little knowledge about how the systems were supposed to work or how they are controlled.
4. There was a general sense of lack of control over essential building comfort factors such as heating, cooling, ventilation and lighting. Comments about inconsistent artificial lighting strategies were common; for example, lights were always left on in some rooms whilst motion sensors were provided in classrooms.
5. In one of the schools, the headmaster had decided to block the only air vents in the reception area, to prevent the noise from the entrance from penetrating into the reception offices.
6. Kettles, heaters, battery chargers and other personal electrical devices were common in many personal office areas and common rooms that staff used for socializing unpredictably increasing electricity consumption.
7. Some computers, television sets and lights were observed to have been left on outside the buildings' hours of operation.
8. Temperature sensors that report to the building management system were sometimes installed in locations distant from the main area of

the activity in the room. In other cases, since staff were not aware of the purpose of these sensors, they had covered them with furniture (and in one case with an electric heater), resulting in a false reading of the room temperature by the BMS.

All these findings emphasise the need for an improved culture of energy monitoring and post-occupancy evaluation.

The whole-school approach, involving children in POE, provided researchers with highly contextualised information about how a school is used, how to improve the quality of users' school experiences (both socially and educationally), how the school community is contributing to the building's energy performance, and reasons for any difference between predicted and actual energy performance. The adapted POE methods also provided unique opportunities for children—whose opinions are usually overlooked—to examine the social and cultural factors impeding the adoption of sustainable behaviours. Students seemed enthusiastic about proposing improvements, and even in open dialogue concern for environmental responsibility emerged, as with the aforementioned student who wanted school staff to apply their own message about energy efficiency by turning lights off. Harnessing this motivation offers a real opportunity for change.

Conclusion

This approach to POE research can contribute to an integrated understanding of energy use in buildings. Dialogue with children and other users of the building provided essential clues explaining differences between the actual and predicted performance of new buildings, including many differences directly traceable to management issues. Moreover, the methods used also offered opportunities to explore children's relationship with their environment and to transform this relationship. These methods are ways to learn about the performance of buildings and to understand people's behaviours toward and within those buildings. POE approaches can both identify and begin to change these behaviours at the level of the school community.

The use of these methods to determine user perceptions offers significant benefits for the design profession, including the advancement of knowledge about use of school buildings; improving design quality; improving energy efficiency; lowering actual energy use in buildings; educational impact, both through improved design and through engaging with young people and thereby improving their understanding of sustainable design; changing behaviours through context-based design initiatives that are attentive to school culture; and allowing construction companies to truly address their social obligation to build more sustainable communities. Whilst more and more buildings are achieving higher energy efficiency ratings, efficiency improvements can be offset by habits and behaviours that often derive from lack of environmental concern. Energy-efficient technology is vital to the future of building design, but in order to actually reduce energy consumption, the relevant human factors must be considered.. The relationship between design and energy behaviours is an essential dimension of the success of low-carbon architecture. Alongside technological innovation, creating a sense that occupants, especially children, can actively engage with their natural, social

and built environments is as important as is building shared values and new social norms.

This goal presents a profound challenge for architects, construction professionals, teachers, school leadership teams and facility managers. Whilst an increased motivation to care for a building and its environment is an essential element of sustainability, concerns of a more day-to-day nature occupied the adult communities of the schools visited. The school rules and regulations were a constant source of conversation for pupils, who perceived their school leadership as imposing irrational rules prohibiting reasonable uses of space. The PFI arrangement was also observed to have a significant impact on school culture, depending on the nature of the school leadership and its relationship with the pupils. Our POE tools were designed to address these tensions and to consider ways to develop different relationships with the school and its environment.

This research has provided information to the design community that is generally not obtained through POEs but is essential in order to address design quality and energy performance in schools. The approach expands the range of persons who should participate in the evaluation process to those who are usually neglected—i.e. children—and extends discussion of energy behaviours within the field of education.

The next generation is likely to be more attentive to the importance of reducing energy consumption than today's adults. New ideas regarding energy efficiency will emerge, and it is important for schools to reinforce positive attitudes towards energy conservation and be critical of "old ways" of using energy. The adults interviewed in this study had often very insightful and critical perspectives regarding the design of their schools, but energy efficiency and environmental awareness were usually low on their list of priorities. Similarly, many of the pupils, even the older ones, had a limited understanding of sustainability and sustainable design. Many blamed adults for their lack of leadership. However, the dialogues with students powerfully demonstrated a wealth of opinion, conviction and desire to develop ways to change school culture and promote energy efficiency. The creative activities offered in this study appeared to be very successful in unleashing and harnessing this potential.

Acknowledgments and dedication

This paper reports results that were part of the PostOPE research project at Loughborough University, supervised by the late Professor Dino Bouchlaghem and carried out whilst the authors were working as his research associates. The research project was supported by two leading construction companies, Loughborough University and the EPSRC. This paper is dedicated to the late Professor Bouchlaghem, an exceptional academic who is greatly missed.

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