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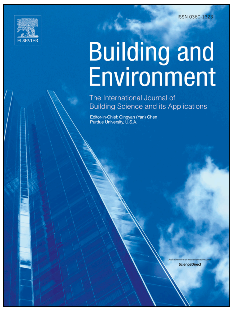
Original citation & hyperlink:
Montazami, Azadeh, et al. "Impact of social background and behaviour on children's thermal comfort." *Building and Environment* 122 (2017): 422-434.
https://dx.doi.org/10.1016/j.buildenv.2017.06.002

ISSN 0360-1323

Publisher: Elsevier

Accepted Manuscript



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PII: S0360-1323(17)30229-9

DOI: 10.1016/j.buildenv.2017.06.002

Reference: BAE 4930

To appear in: *Building and Environment*

Received Date: 21 February 2017

Revised Date: 12 May 2017

Accepted Date: 1 June 2017

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Abstract: This study investigates whether children's thermal perception at home and their dominant behaviour to achieve thermal comfort are related to their socio-economic background and contribute to their thermal perception at school.

The indoor operative temperatures of 27 classrooms were collected during the cooling season of 2014-2015 from eight primary schools located in the West-Midlands, UK. The perception of 603 students aged between 8 and 11 years old about thermal comfort at both home and school and their dominant behaviour in achieving thermal comfort within school was established through questionnaires. Behaviour was studied under two categories of personal behaviour (e.g. adjusting clothing) and environmental behaviour (e.g. asking teachers to open windows). The socio-economic background of the children was investigated through available data.

This paper reveals a relationship between children's socio-economic background and their perception of thermal comfort in primary schools. Results indicate that the behaviour of children differs depending on their socio-economic background. There is a strong relationship between children's thermal perception at home and at school among those that come from less privileged backgrounds. Those from less privileged backgrounds also find their classrooms warmer compared to the other children.

Key words: Primary school, Children's thermal perception, social background, behaviour

1. Introduction:

There is a significant relationship between children's perception of thermal comfort and their academic achievement [1-2]. Research suggests children's perception of thermal comfort is related to the outdoor temperature and there are significant differences between the perceptions of children and adults in the same space [3-7]. Other factors that influence building occupants' thermal perception relate to behavioural adjustment and physiological acclimatization [8-13] which are still among the least covered by scientific research [14].

Behaviour is 'the way in which an animal or person acts in response to a particular situation or stimulus' [15]. Literature suggests that behavioural adjustment depends on an occupants' preferences, their level of understanding and the level of opportunity to control their environment [16]. Some studies suggest the opportunity to control an environment affects the thermal perceptions of occupants, making them more tolerant [8,17-18]. This relationship is complicated in primary schools as the teacher, who normally takes charge of controlling the internal environment, may have a different thermal perception from the children who are the main occupants of the classrooms.

Acclimatisation is 'the process by which an individual organism adjusts to a gradual change in its environment (e.g. temperature), allowing it to maintain performance across a range of environmental conditions' [15]. Very little research has been conducted in this area, although results from a study among children in Chile suggest there might be a relationship between socio-economic vulnerability and children's comfort temperature at school in winter. Those children coming from highly vulnerable backgrounds were comfortable at lower temperatures than those considered less vulnerable [19-22].

The main focus of this study is to evaluate the factors that influence children's perceptions of thermal comfort in primary school classrooms. The first stage evaluates whether children's thermal perceptions at school are affected by their thermal perception at home and their social economic background. The second stage evaluates whether there are any differences in behaviour designed to achieve thermal comfort between children who come from various socio-economic backgrounds.

2. Methodology:

This paper is part of a large case study assessing the quality of indoor environments in primary school classrooms located in Wolverhampton, Hereford and Coventry in the West Midlands, UK. Up to 603 children aged between 8 and 11 years old from 27 classrooms of eight primary schools participated in this study during the cooling seasons of 2014 and 2015. In order to highlight the impact of socio-economic background on children's behaviour and their thermal perception and reduce the impact of indoor temperature on their thermal perception, participating schools were selected from those undergoing regular temperature and energy monitoring [5]. The purpose of this regular monitoring was to make sure that classrooms provide the best thermal conditions with minimum energy consumption. The indoor temperature of participating schools were tested against guidelines suggested by the Department for Education [23] in order to make sure they do not suffer from overheating. By selecting classrooms that have acceptable indoor temperatures, the impact of other factors, including thermal perceptions at home, that may influence children's thermal perceptions at school can be identified. Socio-economic backgrounds of children are inferred using data available from Check My Area website [24] and children's behaviour in achieving thermal comfort in classrooms is established through questionnaires.

The procedure adopted for developing the questionnaire, measuring environmental factors and assuring data quality is outlined below.

2.1. Survey questionnaire

The questionnaire investigated the thermal perception of the children at school and at home as well as their behaviour in achieving thermal comfort at school when they feel hot. The principles of questionnaire design for use with children that were considered include simplicity, using pictures and colours, and adopting an appropriate scale [25]. Simplicity and clarity of questions which helps a child to understand the questionnaire is the fundamental design factor [26].

For this reason, clarity of the questions was checked with several teachers and head teachers and also previous studies [3] before finalising the questionnaire. For example, the 'neutral' temperature corresponding to the central category of the ASHRAE 7-point scale [27] of thermal sensation was changed to 'OK', the 'slightly warm' category was changed to 'a bit warm' and 'slightly cold' was changed to 'a bit cold' in order to provide greater clarity for children. Also, teachers requested that each question was read out in order to eliminate any ambiguity. The lead author and one of the co-authors were present at the time of each survey in order to answer any questions.

The second significant factor is to motivate children to answer the questionnaire [28-29]. In these questionnaires pictures and colours were used as they are thought to be particularly effective. In addition, the lead author ran a short workshop with children before asking them to complete the questionnaire. The aim was to make children familiar with the background to the questionnaire and emphasise that their views are extremely valuable for future generations of schools. Consequently, children were encouraged to fill in the questions more carefully.

The last factor that should be considered in designing questionnaires for children is use of an appropriate rating scale. With adults a descriptive scale with seven unnumbered boxes to be marked by respondents is recommended for each question [30-31]. In comparison, offering children more response options decreases reliability of responses, however according to psychologists, children in their middle to late childhood do not have trouble differentiating between seven categories of response options [25]. For the purpose of this analysis, thermal sensation was measured using a 7 point Likert scale enhanced with colour and descriptions which follows the method used in previous studies [3-4, 16-17, 31], while the thermal preference scale was reduced to a 5-point scale following the teachers' and head teachers' feedback regarding the complicated nature of thermal preference in comparison with thermal sensation.

The questions are divided into four main parts; 1: General background information (i.e. year of study and gender), 2: Clothing information in order to understand if the respondent was wearing a jumper (pullover) while completing the questionnaire, 3: Thermal evaluation both at home and in the classroom, 4: What they do when they feel uncomfortable.

Thermal evaluation at home and at school has been carried out by asking the children to vote about their thermal sensation using the 7-point ASHRAE scale [27] (cold, cool, a bit cool, ok, a bit warm, warm, hot) and thermal preference using 5-point scale (cooler, a bit cooler, as it is now, a bit warmer, warmer). Table 1 illustrates the scales which were used to express their thermal evaluation. In this questionnaire students are asked to vote once about their instant thermal perception (i.e. thermal sensation and thermal preference) at the time of the survey about their classrooms environment and to vote once about their general thermal perception of their home as well as their classroom while they are in their classrooms. In order to prevent any confusion between the general and instant thermal perception, each group of questions was placed on different sides of the questionnaire sheet.

Table 1: The scale used in the questionnaire survey.

TSV Scale Thermal Sensation Vote			TPV Scale Thermal Prefrence Vote	
Hot (+3)	Hot			
Warm (+2)	Warm		Warmer (+2)	☐
A bit warm (+1)	A bit warm		A bit warmer (+1)	☐
Ok (0)	Ok		As it is now (0)	☐
A bit cool (-1)	A bit cool		A bit cooler (-1)	☐
Cool (-2)	Cool		Cooler (-2)	☐
Cold (-3)	Cold			

2.2. Measuring of environmental factors

The indoor operative temperatures in the classrooms were recorded with black globe thermometers at the same time children were completing the questionnaires during parts of the cooling seasons of 2014 and 2015 (i.e. two weeks in July in both years) in all the schools which were participating in this study. A black globe temperature probe (Pt100) with diameter of 40 mm was used. This device measures a range of temperatures between -35 to 80°C, with a high resolution of ± 0.2 degrees Celsius [33].

In six out of eight schools the indoor operative temperature was recorded for the whole cooling seasons of May-July of 2014. The black globe thermometer was placed at the head height of the children far from direct solar radiation.

The outdoor temperature for the duration of survey was retrieved from the meteorological office [34]. The weather stations were generally no more than 5km from the study sites.

Questionnaires were filled in half an hour after students had been sat still in order to eliminate the impact of metabolic rate on their perception. According to the literature, 15 minutes of sedentary activity is sufficient to enable a body to reach a stable state such that it will respond to the prevailing thermal conditions after doing non sedentary activities (e.g. running) [35]. Half an hour has been adopted in previous studies and is considered to provide an appropriate safety margin [3-4, 19-22, 31].

Schools, classrooms and the number of respondents that participated in this study with the date of survey are presented in Table 2. All the schools in this study run under a free running mode during cooling seasons.

Table 2: Summary of all the collected data.

Region	School	Classroom	Monitoring duration (Objective survey)				Subjective survey	
			Long monitoring*	Date	Short monitoring*	Date	Age	Number
Wolverhampton	1	1	✓	Cooling season 2014	✓	07-Jul-14	8_9	24
		2	✓		✓		9_10	21
		3	✓		✓		10_11	27
Wolverhampton	2	4	✓	Cooling season 2014	_	08-Jul-14	8_9	_
		5	✓		✓		9_10	29
		6	✓		✓		9_10	23
Wolverhampton	3	7	✓	Cooling season 2014	✓	10-Jul-14	7_8	21
		8	✓		_		9_10	_
		9	✓		✓		10_11	20
Wolverhampton	4	10	✓	Cooling season 2014	✓	09-Jul-14	7_8	20
		11	✓		✓		7_8	23
		12	✓		✓		10_11	26
		13	✓		✓		10_11	25
Wolverhampton	5	14	✓	Cooling season 2014	✓	11-Jul-14	9_10	26
		15	✓		✓		10_11	28
Herefored	6	16	✓	Cooling season 2014	✓	14-Jul-14	8_9	28
		17	✓		✓		10_11	24
		18	✓		✓		10_11	25
		19	✓		✓		10_11	24
Coventry	7	20	_	Cooling season 2015	✓	01-Jul-15	9_10	19
		21	_		✓	01-Jul-15	10_11	19
		22	_		✓	09-Jul-15	10_11	26
		23	_		✓	09-Jul-15	10_11	33
Coventry	8	24	_	Cooling season 2015	✓	01-Jul-15	9_10	19
		25	_		✓		9_10	29
		26	_		✓		10_11	22
		27	_		✓		10_11	22

* Long monitoring = Temperature monitoring occurred for the duration of cooling season
* Short minotoring= Temperature monitoring occurred when children voted about their instant thermal perception

2.3. Quality assurance

In order to evaluate how factors such as temperature, thermal experience at home and types of behaviour that children adopt when they feel hot have an impact on children's thermal sensation, a set of consistent data is required. For this reason there is a need to refine the data and exclude any inconsistencies before carrying out the main analysis. The process of refining data eliminates the responses of the children who have not demonstrated an ability to share their perceptions of thermal comfort or have misinterpreted the questionnaire. For example, this could be where children expressed a wish to be warmer while indicating that they already feel hot. It is suggested that these cases can be identified by adding up thermal sensation vote (TSV) and thermal preference vote (TPV). The case where (TSV+TPV) <-2 or (TSV+TPV)>2 were considered as inconsistent based on the fact that TSVs within [-3,-2] and [+2, +3] are thought to express dissatisfaction and one would not normally wish to enhance that sensation. This is based on the fact that a thermal sensation vote outside the 3 central categories is considered to express dissatisfaction [36]. The approach of refining data has been adopted from the previous studies [3-4].

According to previous research a 'neutral' thermal sensation is not always a preferred option and slightly warmer [+1] or slightly cooler [-1] can be the favoured option based on the climate conditions [37-38].

As a result, the extreme cases have been excluded from the data set for measurements of both instant perception and general perception (Figure.1). Inconsistencies which were excluded from the data set represent around 5% to 8% which suggests that a majority of children are capable of understanding the questionnaire. These figures are in line with a similar study where 7% of data were excluded [3].

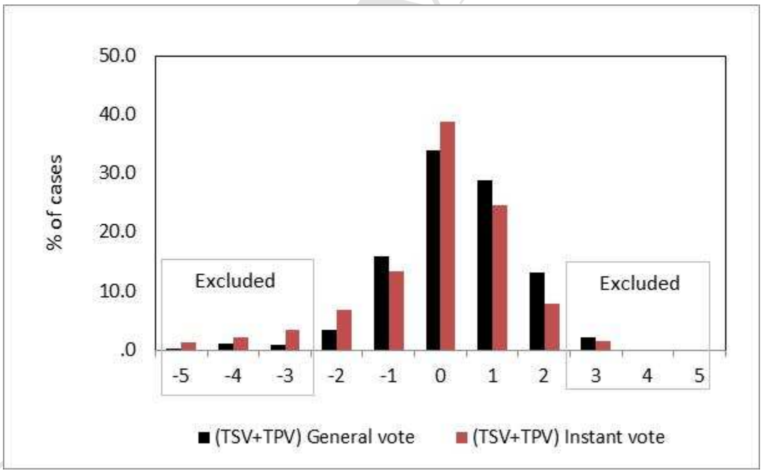


Figure 1: Excluded children responses from the thermal comfort questionnaire considering both instant and general thermal perception.

3. Analysis:

3.1. Classroom potential to achieve a thermally comfortable condition:

The aim of this part of this study is to evaluate the potential of classrooms to achieve thermally comfortable conditions and study if factors other than classroom conditions have an impact on the thermal perception of children.

According to Nicol *et al.,* [27] and the Technical Memorandum No.52 published by CIBSE [36], occupant discomfort is related to ΔT, the difference between the actual operative temperature (T_{op}) in the room and the comfort temperature (T_{comf}) in a free-running building ($\Delta T = T_{op} - T_{comf}$). Based on European Standard EN 15251 [36], the comfort temperature (T_{comf}) in summer is calculated from Equation (1):

$$T_{comf} = 0.33\ T_{rm} + 18.8 \qquad (1)$$

Where T_{rm} is the running mean of the outdoor temperature which is calculated from

$$T_{rm} = (1-\alpha).\{T_{od\,-1} + \alpha.\ T_{od\,-2} + \alpha^2\ T_{od\,-3}\ldots..\} \quad \text{where } 0<\alpha<1 \qquad (2)$$

Where

- T_{od-1} is the daily mean external temperature for the previous day
- T_{od-2} is the daily mean external temperature for the day before and so on

In equation (2), the larger the value of α, the more important the past experience will be. For a series of days the value of T_{rm} for any day can be simply calculated from the value of the running mean temperature and the mean outdoor temperature for the previous day (T_{rm-1} and T_{od-1}):

$$T_{rm} = (1-\alpha)\ T_{od-1} + \alpha\ T_{rm-1} \ (3)$$

The optimal value of α to use in calculating the changes in indoor comfort temperature has been investigated using data from comfort surveys conducted throughout Europe.

Where an extensive run of days is not available, BS EN 15251 (BSI 2007) gives an approximate calculation methods using the mean temperature for the last seven days (α=0.8) [40]. This approach has been adopted for the purpose of this analysis.

BS EN 15251 suggests that the likelihood of occupants feeling uncomfortable relates to the comfort temperature as well as the type of building and occupants. Building Category I is considered to include buildings where the occupants are particularly sensitive and fragile (vulnerable group), whereas Building Category II is considered for normal expectations in new or renovated buildings. Eqs (4) and (5) show the maximum allowable temperature (i.e. thermal comfort threshold), T_{max}, in Building Categories I and II respectively [40].

- (Category I) T_{max} (°C) = 0.33 T_{rm} +20.8 (4)
- (Category II) T_{max} (°C) = 0.33 T_{rm} +21.8 (5)

Results from the few studies on thermal comfort in primary school classrooms suggest that children want the indoor environment about 2-3°C cooler compared to adults during the cooling season [2-3, 5, 41]. This suggests that children are more likely to respond in line with Building Category I occupants, assuming that their teachers have normal expectations of comfort.

According to the Technical Memorandum No.52 (TM.52) published by CIBSE [39] and Building Bulletin 101 published by the Department for Education [23], a classroom would be at risk of overheating if any two of the following three criteria are exceeded.

- Criterion 1 - Hours of Exceedance (H_e): For schools, the number of hours (H_e) that ΔT is greater than or equal to one Kelvin (K) during the period 1st May to 30th September for the defined hours inclusive shall not be more than 40.
- Criterion 2 – Daily Weighted Exceedance (W_e): To allow for the severity of overheating the weighted Exceedance (W_e) shall be less than or equal to 6 in any one day. The weighting is given by multiplying the hours ΔT exceeds the limit by the value of ΔT each hour.
- Criterion 3 - Upper Limit Temperature (T_{upp}): To set an absolute maximum value for the indoor operative temperature the value of ΔT shall not exceed 4K.

ΔT in the above criterion is the difference between indoor operative temperature and comfort temperature which is calculated based on equation (4).

a) Long term monitoring

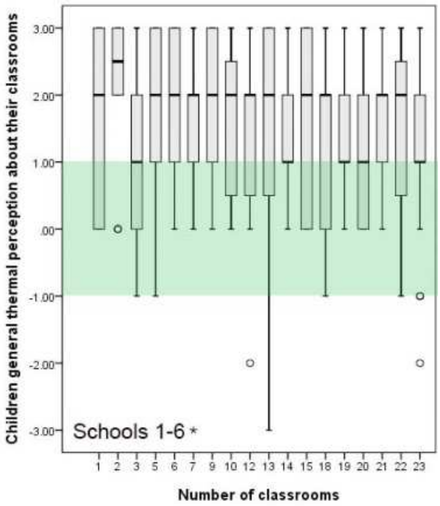
In this study a long term monitoring programme recorded indoor temperatures of 19 classrooms from schools 1-6 (Table 1) every fifteen minutes using black globe thermometers. The risk of overheating was calculated for all the classrooms from these six schools during the cooling season considering thermal comfort conditions for both Category I buildings (vulnerable occupants, Equation 3)and Category II buildings (normal occupants Equation 4).

Results presented in Table 3 suggest classrooms from schools 1-5 not only satisfy thermal comfort for adults calculated using Equation (4) (i.e. normal occupant) but they also satisfy thermal comfort for children calculated using Equation (3) (i.e. for vulnerable occupants). All the three conditions that have been put in place by TM52 [39] and BB0101 [23] are evaluated in Table 3. In school 6, only one classroom (C.22) fails to provide a comfortable condition for children (e.g. vulnerable occupant). Due to the fact that 22 out of 23 classrooms can satisfy thermal comfort requirements for both adults and children, it is expected that children from these 22 classrooms should be generally satisfied with the thermal conditions.

Table 3: Evaluating overheating risk in schools 1-6 considering normal and vulnerable occupants.

Themal comfort benchmark	Primary School	School.1			School.2				School.3				School.4				School.5				School.6			
	Classrooms	C.1	C.2	C.3	C.4	C.5	C.6	C.7	C.8	C.9	C.10	C.11	C.12	C.13	C.14	C.15	C.16	C.17	C.18	C.19	C.20	C.21	C.22	C.23
Category II (T max = Tcomf+3)	Meet Criterion 1	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
	Meet Criterion 2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Meet Criterion 3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Overheating risk based CAT II	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Category I (Tmax = Tcomf+2)	Meet Criterion 1	✓	X	✓	X	✓	X	✓	✓	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
	Meet Criterion 2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
	Meet Criterion 3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Overheating risk based CAT I	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P
Avalibility of subjective data		Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y

Figure 2 shows the range of children's general sensation of the thermal conditions in their classroom in schools 1 to 6 during the cooling season. Although all except one of the 23 classrooms from schools 1 to 6 satisfy the thermal comfort requirements (Table 3), in a majority of cases the average thermal sensation is outside the acceptable range of a bit warm (+1) to a bit cold (-1), (Figure 2). Such variance in the thermal perception vote to outside of the boundaries of thermal comfort for classrooms that are comfortable according to the existing comfort criteria, suggest that factors other than the indoor temperature of classrooms may have an impact on children's thermal sensation.



Shaded area refers to the entire vote between +1 (A bit warm) and -1 (A bit cold) which is considered as a comfortable range.

Figure 2: Children's general thermal sensation of their classroom.

b) Short term monitoring

A short term monitoring survey was carried out in schools 1-8 located in Wolverhampton, Hereford and Coventry. In this survey, the classrooms' indoor temperature was recorded while, at the same time, students were requested to vote about their thermal perception. Figure 3 shows the instantaneous recorded temperature of the classrooms at the time at which children voted about the indoor conditions of their classroom. For all of the classrooms, indoor temperature (Instant temperature, Figure 3) was plotted against the adaptive comfort temperature for children (i.e. vulnerable occupants) which is illustrated as T_{Comf}.CAT I and the adaptive comfort temperature for adults (i.e. normal occupant) which is illustrated as T_{Comf}.CAT II.

The indoor temperatures of 20 out of 26 classrooms are within the comfortable range for both children and adults (Instant temperature < T_{comf}.CAT I). In addition, the indoor temperatures of 4 classrooms are within the comfortable range for adults but not children (T_{comf}.CAT I < Instant temperature < T_{comf}.CAT II). Out of these 26 classrooms there are 2 classrooms in which the indoor temperature would not be suitable either for children or adults (Instant temperature > T_{comf}.CAT II) (Figure 3).

It is expected that the thermal perception of children in classrooms in which the indoor temperature is within the comfortable range for both children and adults will be within the acceptable range of -1 (A bit cold) to +1 (A bit warm). However, Figure 4 suggests that the range of thermal perceptions in these classrooms goes beyond this range. Such variance in the thermal perception vote, to the outside of the boundaries of thermal comfort for classrooms that are completely comfortable, suggest that factors other than indoor temperature may have an impact on children's instant thermal perception.

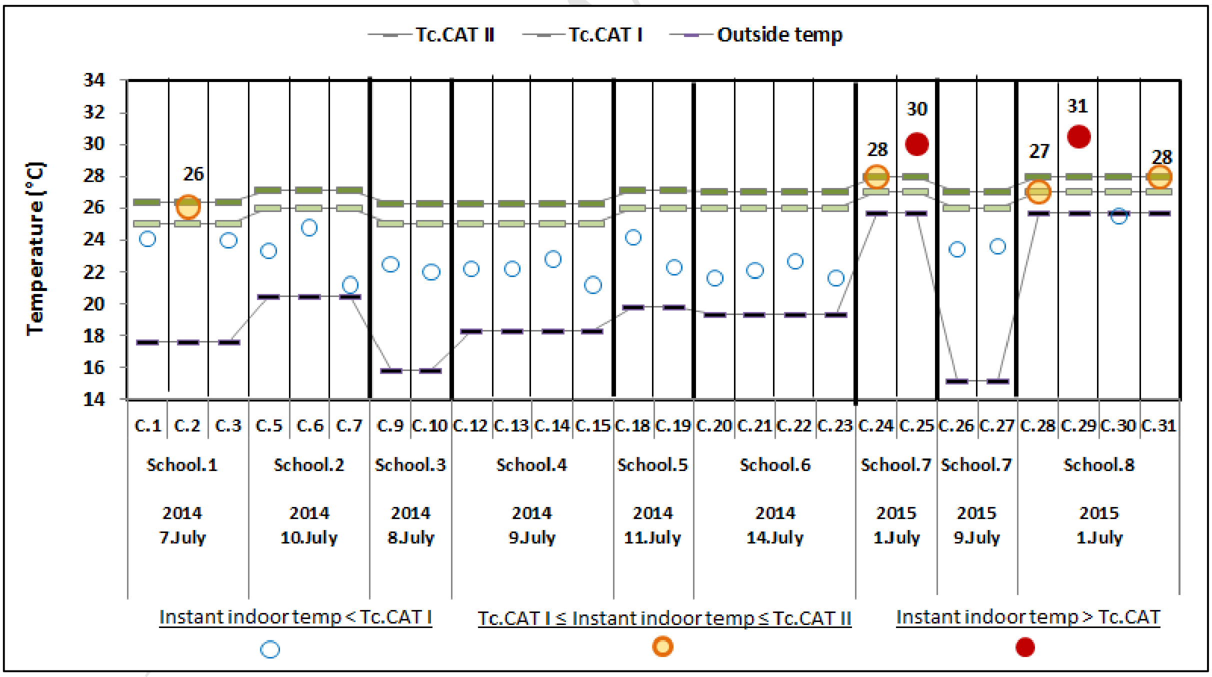
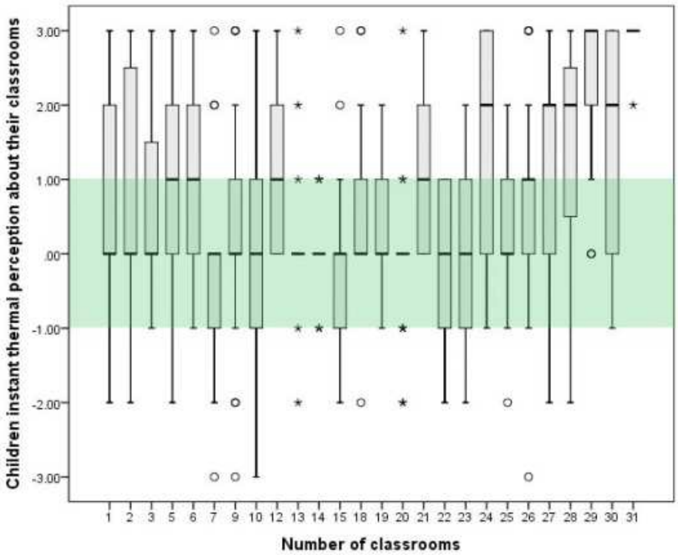


Figure 3: Comparison of classroom indoor temperatures with children's comfort temperature. (T_{comf}.CAT I) and adult comfort temperate (T_{comf}.CAT II).



Shaded area refers to the entire vote between +1 (A bit warm) and -1 (A bit cold) which is considered as a comfortable range.

Figure 4: Children's instant thermal sensation about their classrooms

These results suggest that while a majority of the classrooms satisfy the current thermal comfort guidelines some children are dissatisfied with the conditions in such classrooms. Such discrepancies between the thermal sensation vote of children and actual thermal conditions in classrooms, suggest that factors other than indoor temperature may have an impact on both children's general and instant thermal sensation. For this reason the thermal perception of children outside the classrooms (i.e. at home) and also their behaviour to achieve thermal comfort in classrooms are investigated below.

3.2. Factors affecting children thermal sensation at school

This section discusses how the indoor temperature, occupants' behaviour and thermal experience at home have an impact on children's thermal perception at school.

3.2.1. Indoor temperature

Children's thermal perception in a classroom is affected by indoor temperature and also by other factors such as outside classroom thermal exposure [7], behaviour [8-13], metabolic rate [35], etc. In a thermally uncomfortable classroom (i.e. too hot and too cold), the impact of other factors would be less obvious in comparison to indoor temperature. In order to specifically identify the influence of indoor recorded temperature on children's thermal perception at school, regression analysis was carried out between children's instantaneous thermal perceptions and recorded indoor temperature at the time of survey, initially considering all the classrooms and then considering only the comfortable classrooms. Eliminating the uncomfortable classrooms from the data set provides an opportunity to highlight the percentages of other factors that have an impact on children's thermal perception more clearly.

The results suggest that when all classrooms are considered, 17% of the variation of the children's perceptions can be explained by the variation in indoor temperature ($P = 0.000 < 0.05$, $R^2 = 0.17$). This result is reduced to 6% ($P = 0.000 < 0.05$, $R^2 = 0.06$) when only comfortable classrooms are included. Figure 5 shows the distribution of children's thermal sensation and preference votes in both groups; comfortable classrooms and all classrooms.

The percentage satisfaction in a group of comfortable classrooms is significantly higher (74% satisfaction) in comparison with that for the entire sample (67% satisfaction).

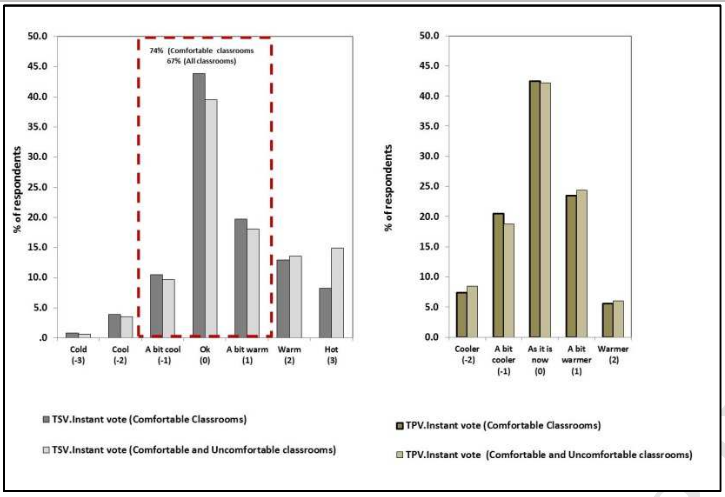


Figure 5: Relative frequency of instantaneous thermal sensation vote (TSVs) (left) and the thermal preference vote (TPVs) (right) for using both comfortable classrooms and the entire sample (Comfortable and Uncomfortable classrooms) at the time of survey.

Results from the regression analysis and frequency analysis suggest that the thermal sensation of children in a sample from only the comfortable classrooms is less affected by indoor temperature and likely to be more influenced by other factors in comparison with a sample from all classrooms (comfortable and uncomfortable classroom together).

3.2.2. Impact of social economic background on children's thermal perception at school

Previous research suggests that the thermal environment experienced at home contributes to perceptions at school [19-22]. To investigate whether such findings are reflected in schools analysed in this study, the instant and general thermal perception (i.e. sensation and preference) in classrooms and general thermal perception (i.e. sensation and preference) at home are questioned through a 7-point ASHRAE thermal sensation scale (cold, cool, a bit cool, ok, a bit warm, warm, hot) and a 5-point thermal preference scale (cooler, a bit cooler, as it is now, a bit warmer, warmer).

Regression analysis was carried out between children's thermal sensation and preference at home and in classrooms using the responses from comfortable classrooms. The results suggest that children's thermal experience in classrooms is significantly affected by their thermal experience at home (Table 4).

Table 4: The relationship between children's thermal perception (i.e. sensation and preference) at home and children's thermal perception (i.e. sensation and preference sensation) at school.

		Home	
		General Thermal Sensation (TSV.G)	General Thermal Prefrence (TPV.G)
Classroom	General Thermal Sensation (TSV.G)	(n=603, P = 0.000 <0.05) (R^2=0.10, %10 related)	–
	General Thermal Prefrence (TPV.G)	–	(n=603, P = 0.000 <0.05) (R^2=0.16, %16 related)
	Instant Thermal Sensation (TSV.In)	(n=569, P = 0.000 <0.05) (R^2=0.08, %8 related)	–
	Instant Thermal Prefrence (TPV.In)	–	(n=563, P = 0.000 <0.05) (R^2=0.11, %11 related)

Figures 6 and 7 show the range of votes at home with respect to their vote in classrooms considering the instant and general thermal perception. In this analysis a 'Cold' vote represents the cold and cool responses, an 'Ok' vote represents a bit cool, ok and a bit warm responses, and 'Hot' represents warm and hot responses. Results suggest a large number of children (60%-70%) who voted Hot in their classrooms, voted Hot at home according to instant and general vote. These two graphs also show that a significant number of children (58%-65%) who are comfortable and voted Ok in the classroom also voted Ok at home according to instant and general vote. However, the ones who voted Cold in their classrooms are not Hot at home.

This part of study suggests that children's thermal perception in the classrooms is significantly related to their thermal perception at home. It is more likely that the children who are comfortable at home are comfortable in classrooms and those that are uncomfortable at home are uncomfortable in the classroom. This study confirms the finding of a field study in Chile, which introduces the relationship between socio-economic vulnerability of the children and their comfort perception at school [19-22].

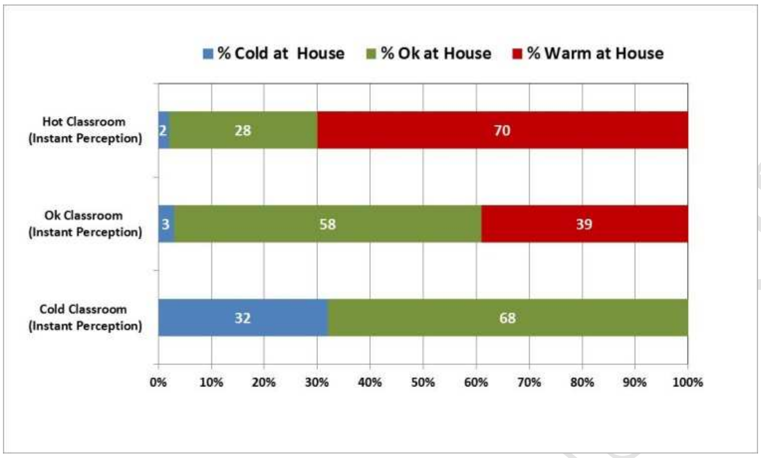


Figure 6. Relationship between children's thermal perception at classroom and home (Based on Instant Vote).

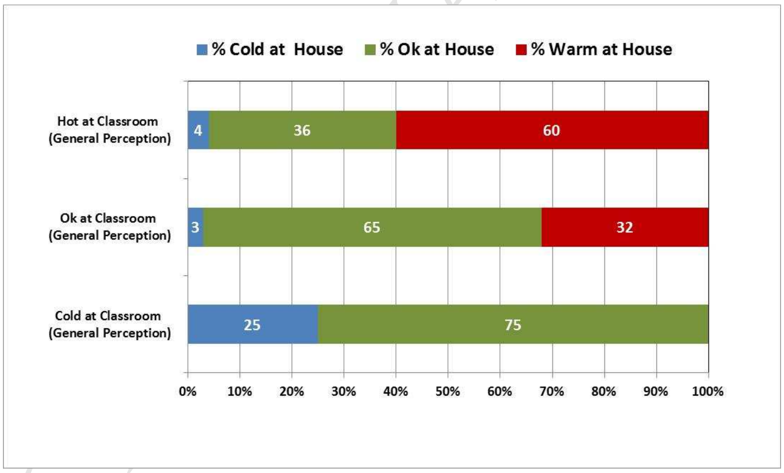
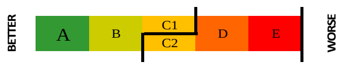
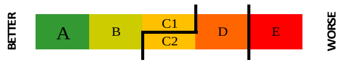
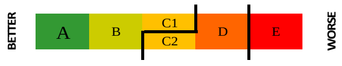
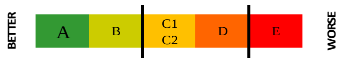
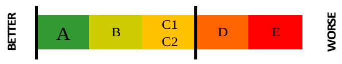
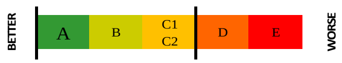


Figure 7. Relationship between children's thermal perception at classroom and home (Based on General Vote).

Data presented in Table 4 suggest home thermal sensation plays up to a 10% role on thermal sensation in classrooms. The next stage is to evaluate whether children's thermal perception at school differs according to their socio-economic background and also test if there are any differences between their thermal perceptions at home based on their socio-economic background.

The term ‘socio-economic class’, usually synonymous with ‘social class’, is defined as people having the same social, economic, or educational status [42]. In this study two factors of economic and educational status are considered as the main factors dividing social background. These two factors can be represented by a parent’s occupation (which is related to their educational status) and also quality of their accommodation (which is related to their economic status). Therefore, children who participated in this study are categorised to five groups of 'Privileged', 'Average', 'Below Average', 'Non Privileged' and 'Mixed' by considering the quality of their homes and their parents’ professional classification who are living within the catchment of each school. Data used in this analysis were retrieved from the ‘Check My file’ website. The ‘Check Any Postcode’ service on the Check My File [24] website is collated using information from two sources of geodemographic data: Cameo and Censation. Cameo is owned by Eurodirect Marketing and is one of a handful of geodemographic databases that are commercially available in the UK. Cameo classes every postcode into one of around 50 postcode classifications, which in turn are based on information from many sources including insolvency and court information, questionnaires and census data. Censation is owned by AFD Software and classifies every UK postcode using the latest and most comprehensive data about where people live, how affluent or deprived they are and what 'life stage' they are in. Information about housing, employment, and qualifications, using over 600 variables from the latest UK Census,are analysed together with residential and commercial data and then validated further using a life-style database [24].

Table 5: Categorising occupants of the schools based on their social economic background (CRAL, 2000) .

School	Professional classification	Description of properties						Social Class
		Type	Size	Location	Years of living	Ownership	Price	
School.1		• Semi detached • Terraced	• Smaller than average	• Large/small town • Suburb	• Any number of years	• Mortgaged • Council house	• Very low	**Not Privileged**
School.2		• Semi detached • Terraced	• Smaller than average	• Suburbs • Rural	• 4-11 years	• Owned • Mortgaged • Council house	• Very low	**Below average**
School.3		• Semi detached • Terraced	• Smaller than average	• Suburbs • Rural	• 4-11 years	• Owned • Mortgaged • Council house	• Very low	**Below average**
School.4		• Semi detached • Terraced	• Average	• Inner city • Suburbs	• 4-11 years	• Owned • Mortgaged • Privately rented	• Below average	**Average**
School.5		• Mainly detached • Semi detached • Flat	• Large	• Suburb • Rural • Coastal	• 1-3 years	• Owned • Mortgaged	• Average	**Privileged**
School.6		• Mainly detached • Semi detached • Flat	• Large	• Suburb • Rural • Coastal	• 1-3 years	• Owned • Mortgaged	• Average	**Privileged**
School.7		• Mixed	• Average	• Mixture	• 0-10 years	• Mortgaged • Council house • Housing association • Privately rented	• Low	**Mixed**
School.8		• Mixed	• Average	• Mixture	• 0-10 years	• Mortgaged • Council house • Housing association • Privately rented	• Low	**Mixed**

Legend for professional classification		
	A	Professionals such as doctors, lawyers and dentists, chartered architects and engineers. Individuals with a large degree of responsibility such as senior executives and senior managers, higher grade civil servants and higher ranks of the armed services
	B	University lecturers, heads of local government departments, executive officers of the civil service, middle managers, qualified scientists, bank managers, police inspectors and senior ranks of the armed services
	C1	Nurses, technicians, pharmacists, salesmen, publicans, clerical workers , clerical officers within the civil service, police sergeants and constables and senior non commissioned officers within the armed services.
	C2	Skilled manual workers who have served apprenticeships; foremen, manual workers with special qualifications such as long distance lorry drivers, security officers and other non commissioned officers within the armed services.
	D	Semi-skilled and unskilled manual workers, including labourers and people serving apprenticeships; clerical assistants in the civil service, machine minders, farm labourers, laboratory assistants, postmen and all other members of the armed services.
	E	Pensioners, casual workers, long term unemployed people, and others with relatively low or fixed levels of income.

Table 5 shows the professional classification of occupants that live within the catchment of each school and a description of their properties. The professional classification is coded under six categories of A, B, C1, C2, D and E. The properties are explained under type, size, location, years of residence, ownership and price of the property.

Based on these data children who are participating in this study are grouped into five social classes: ‘Privileged’, ‘Average’, ‘Below Average’, ‘Non Privileged’ and ‘Mixed’ considering their parents’ profession and also the type of house in which they are living.

- **‘Privileged’:** Children of schools 5 and 6 are classed as children with privileged socio-economic background. These children usually live in a large detached, semi-detached houses or flats which are located in a coastal, rural or suburban area. Their parents either own the property or it is mortgaged and have a profession under the A, B, C1 or C2 category.
- **‘Average background’** Children of school 4 are classed as children with average socio-economic backgrounds. These children usually live in average sized houses which are either semi-detached or terraced and are located in inner city or suburban areas. Their parents either own the property, have a mortgage on it or privately rent it and have a profession under the category of C1, C2 or D.
- **‘Below Average background ’**: children of schools 2 and 3are classed as children with below average socio-economic backgrounds. These children usually live in a smaller than average sized house which are semi-detached or terraced and are located in suburban or rural areas. Their parents own the property, have a mortgage on it or are social housing house tenants; their professions are under the C2 or D category.

- **'Not privileged background'**: children of school 1 are classed as children with no privileged socio-economic background. These children usually live in a smaller than average sized houses which are semi-detached or terraced and located either in towns or suburbs. Their parents have mortgaged properties or are social housing tenants and have a profession under the C2, D or E category.
- **'Mixed background'**: children of school 8 are classed as children with mix socio-economic backgrounds. . These children live in a variety of houses from privately rented to social housing. Their parents' profession ranges from A to E categories.

These characterisations allow the potential impact of social economic background and children's experiences at home on their thermal perception at school to be investigated. Table 6 shows the relationship between children's thermal perception at home and in their classroom according to their socio-economic background, as well as the percentage of children who voted 'Hot' at home according to their social economic background.

Table 6: The relation between thermal perception in classrooms and at home (left columns) & percentage of 'Hot' vote (right column) according to socio-economic background.

School. Number	Social. Class	Relation between General House thermal perception & General Classrooms thermal perception				Hot thermal perception at home
		Relationship		R^2	Relation	
School 1	Not privileged	✓	Sig (P = 0.003 <0.05)	0.14	14%	53%
School 2	Below Average	✓	Sig (P = 0.007 <0.05)	0.11	10%	31%
School 3	Below Average	✓	Sig (P = 0.011 <0.05)	0.10	10%	28%
School 4	Average	✓	Sig (P = 0.024 <0.05)	0.06	6%	17%
School 5	Privileged	X	No Sig (P = 0.365 > 0.05)	_	_	19%
School 6	Privileged	X	No Sig (P = 0.115 > 0.05)	_	_	15%
School 7	Mixed	✓	Sig (P = 0.021 <0.05)	0.07	7%	24%
School 8	Mixed	✓	Sig (P = 0.000 <0.05)	0.12	12%	48%

Figure 8 presents data from Table 6 graphically. Results suggest there is a stronger relationship between children's thermal perception at home and in a classroom for those from less privileged backgrounds compared to those from average or below average backgrounds. There is no relationship between children's thermal perception at home and at school among children from privileged backgrounds. In addition, the percentages of children who feel their home is hot are significantly higher among the children from less privileged backgrounds compared to those from privilege backgrounds.

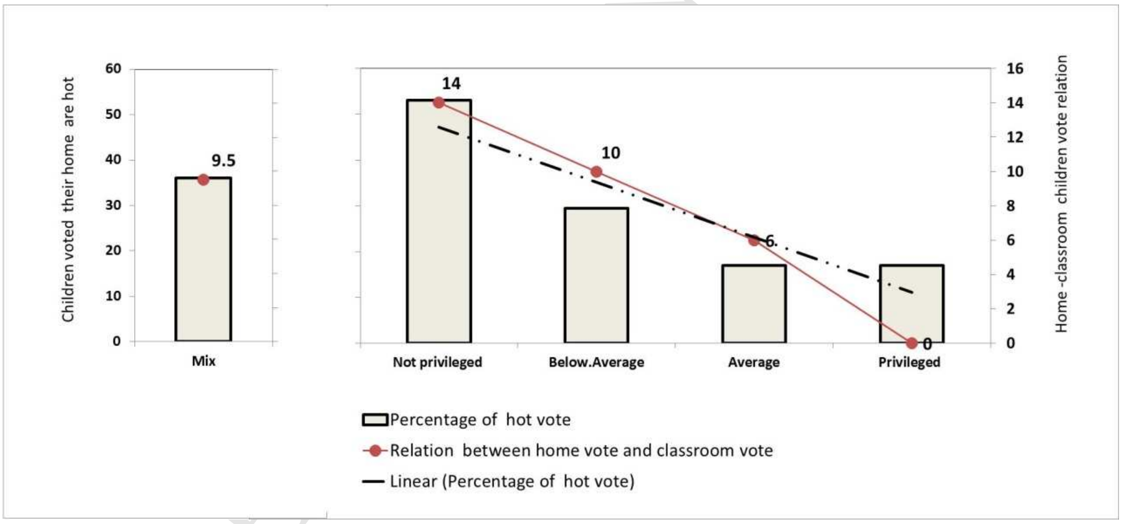


Figure 8: Percentage of 'home hot vote' and 'home-classroom vote relation' according to children's socio-economic background.

3.2.3 Behaviour

Studies show that the level of opportunity to control and adjust their immediate environment may impact on an occupant's thermal perception [8,18]. In this part of the study, the impact of children's behaviour on thermal comfort and also their types of behaviour in achieving thermal comfort within the classrooms are investigated. Children were questioned about their instant and general thermal perception as well as their main approaches to achieving thermal comfort in their classrooms when they feel hot. These approaches can be categorized under ' personal changes' which can be the removal of jumpers, drinking water, fanning themselves, sitting still (in order to reduce their metabolic rate) or 'environmental changes' which can be asking teachers to open the classroom window/door or requesting teacher's permission to open the window/door.

A regression analysis was carried out between the percentages of children who generally feel comfortable (voted between 'a bit cold' to 'a bit warm') in each classroom and the main types of behaviour that they apply to achieve a comfortable condition. The results suggest that there is a significant relationship between the percentage of children who feel comfortable in a classroom and the types of behaviour that children adopt when they feel hot ($P = 0.00 < 0.05$).

In order to study if the social economic background and the type of school building have an impact on children's behaviour in achieving thermal comfort in classrooms, Chi Square tests were carried out. Results suggest that that socio economic background has a significant impact on a child's behaviour (X^2=13.83, df=3, P= 0.003< 0.05) while no relationship was evident between the type of school building and a child's behaviour (X^2=3.08, df=2, P= 0.213>0.05). Consequently, children from privileged backgrounds are more likely to have an ability to make an independent decision and adopt personal behaviour while children from less privileged backgrounds are more likely to adopt environmental behaviour and be dependent on the actions of teachers.

The percentage of children who adopted personal and environmental behaviour according to their socio economic backgrounds are evaluated in Figures 9 and 10.

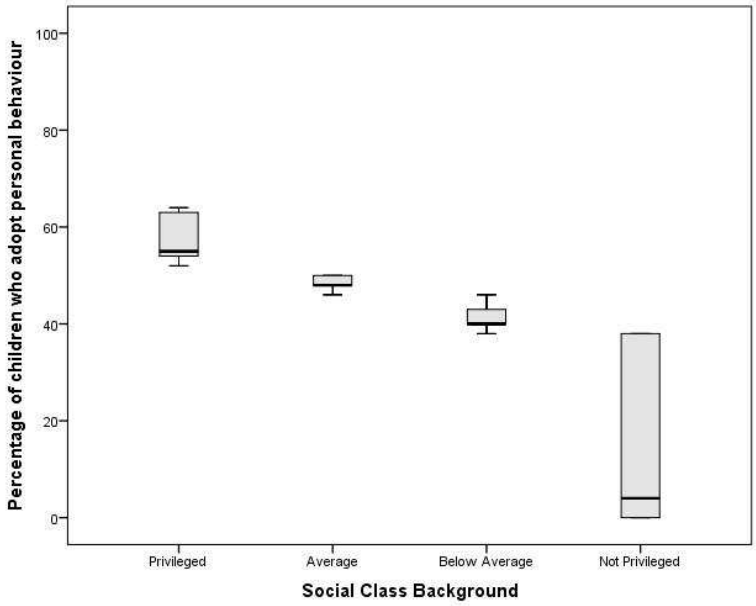


Figure 9: The impact of social economic backgrounds on children personal behaviour.

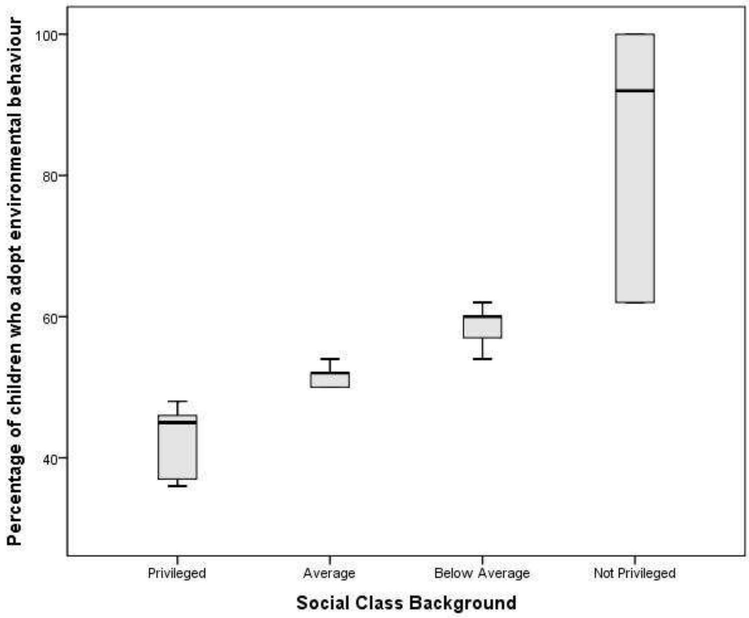


Figure 10: The impact of socio-economic background on children's environmental behaviour.

4. Discussion

This study investigated the impact of socio- economic background and behaviour on children's thermal perception at school. Results suggest that the perception of thermal comfort is not purely dependent on indoor temperatures in classrooms but can be affected by children's socio-economic background and what they experience at home. This study highlights that what children experience at home and also their dominant behaviour in achieving thermal comfort contributes to their thermal perceptions in their classrooms.

The causal relationships identified in this study are supported by the evidence available in the literature regarding both the impact of housing types and location [42-49] on indoor comfort conditions and the impact of socio-economic background on decision-making processes [50-53]. For example, during the summer term, children from the less privileged backgrounds are more likely (up to 14%) to be affected by their thermal perception at home while children from privileged backgrounds are less likely to be affected. In addition more than half of children from the less privileged backgrounds indicated that their homes are hot which may relate to the high internal gain as the result of being overcrowded. In the support of this outcome there is evidence, that social housing has the highest rate of overcrowding in the UK [42,53]. Such overcrowding is likely to raise levels of internal heat gain and consequently increase indoor temperatures [55], particularly during the cooling season.

In addition, children's behavioural approach to achieving thermal comfort within their classroom environment when they feel hot is significantly related to their socio-economic background. The ability to make an independent decision is related to higher levels of self-esteem and self-esteem is thought to be a function of socio economic background [50] Indeed, results from this analysis suggest that children from privileged backgrounds are more independent in making decisions to overcome their thermal discomfort and their main approach is personal behaviour when they feel hot (i.e. taking off jumper, drinking water, fan themselves etc.) while children from less privileged backgrounds are more likely to rely on actions carried out by others (i.e. ask teachers or classmates to open the window, or ask permission from teacher) in order to achieve thermal comfort.

These findings have potentially far reaching consequences for the design of effective learning environments, particularly in primary schools. It is already clear that designers need to go beyond current guidelines that rely on simply achieving targets for a number of quantitative environmental parameters. These are unlikely satisfy all the children in one classroom due to the different thermal perceptions between children and their teacher and also amongst children who come from different socio-economic backgrounds. Revised guidelines should consider the potential differences in thermal preferences between children and their teachers [2-3, 5, 41]. However, they also need to reflect on the socio-economic background of the children to ensure both thermal perceptions and the most effective ways of helping children meet their individual comfort needs are understood.

5. Conclusion:

The socio-economic background of children is likely to influence their perceptions of comfort in primary school classrooms and the behaviour that they adopt to adjust their individual comfort. In particular, thermal experiences at home are likely to be reflected in their thermal perception in the classroom. Therefore, it is possible that a significant minority of children could be dissatisfied with the indoor conditions in a classroom regardless of the actual environmental conditions. Similarly, children from particular backgrounds might not feel sufficiently empowered to take control of managing their own comfort with the concomitant impact on learning. Understanding the nature of such preferences could help predict sensitivities of children; providing teachers with the opportunity to manage the environment more effectively.

In short, the outcome of this study be of interest of architects, teachers, engineers, school administrators and policy makers because it would help to provide insight on the factors that influence children's perception of thermal comfort as well as to determine if those perceptions are influenced by their thermal experience at home. These professions need to work to ensure a broader range of considerations inform design guidelines in order to deliver effective school environments.

The influence of conditions at home on thermal perception in the classroom can be the result of thermal exposure at home or of the behaviour which children adopt to achieve thermal comfort. There is a need for further investigation of how and to what extent, each of these factors will influence children's thermal perception at school during both cooling and heating seasons. The research reported in this paper suggests that both the availability of the different adaptive opportunities and the social economic background of the children will influence their approach to achieving thermal comfort. The interrelation between these factors will need to be explored in further research the outcome of which could be used to inform design guidelines for schools and help to suggest the design of suitable adaptive opportunities in the future.

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Acknowledgement:

This study is part of the Knowledge Exchange and Enterprise Network (KEEN) project between Coventry University and Architype ltd., led by Dr.Azadeh Montazami. This project funded by the ERDF and Architype (KEEN 107/A). We would like to extend our thanks to Michael Humphreys for all of his valuable advice. We are grateful for the assistance from the head-teachers, staff and students of the case study Primary Schools. External weather information was kindly provided by the Met Office.

Highlights

1. Children's thermal perception is not only related to a classroom's indoor temperature
2. There is a relationship between children's thermal perceptions at school and home
3. Children's thermal behaviour is affected by their socio-economic background
4. Children from privileged backgrounds use personal changes to achieve thermal comfort
5. Children from non-privileged backgrounds use environmental changes to achieve comfort