Metabolic rate and clothing insulation data of children and adolescents during various school activities

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Abstract

Data on metabolic rates (n=81) and clothing insulation (n=96) of school children and adolescents (A, primary school: age 9-10; B, primary school: age 10-11 year; C, junior vocational (technical) education: age 13-16 (lower level); D, same as C but at advanced level; and E, senior vocational (technical) education, advanced level: age 16-18) were collected (Diaferometer, Oxylog, Heart Rate derivation) during theory-, practical- and physical education- lessons. Clothing insulation was calculated from clothing weight, covered body surface area, and the number of clothing layers worn. Clothing insulation was found to be similar to that expected for adults in the same (winter) season, with minimal variation with age or school type (0.9 to 1.0 clo; 1.38 clo where coverall was worn), but more variation within groups (coefficient of variation 6-12%). Metabolic rate values ($W.m^{-2}$) were lower than expected from adult data for similar activities, but are supported by other child data. The results of this study can be used to establish design criteria for school climate control systems or as general data on energy expenditure for children and adolescents. The results emphasise the need for specific child data and shows the limited value of size-corrected adult data for use in children.

1. Introduction

In the evaluation of thermal comfort in buildings and in the specification of design guidelines for heating and air conditioning systems for occupied spaces, extensive use is made of the calculation of the human heat balance in relation to subjective thermal comfort votes. This relation was formalised by Fanger (1970) and later transformed into an international standard (ISO 7730 2005). The thermal comfort sensation of building occupants is determined by the climatic parameters (room temperature, humidity, air speed and radiation levels) and by personal factors such as the activity and clothing level of the occupants (Havenith *et al.* 2002). The motivation for the present study was to collect data needed for the determination of design specifications of school buildings. In this application, climatic requirements for thermal comfort are deduced from clothing insulation and activity levels of the building occupants, using ISO 7730 (2005). Other applications for such data can be found in the areas of child nutrition (Torun 1989). Hence, this is not a hypothesis driven study, but a data gathering study.

Clothing insulation in pupils will vary depending on the season and on the lesson type. The latter will be the case when special clothing is worn. Examples are the use of Physical Education (PE) uniforms (sports clothing) in Physical Education lessons, lab coats in Chemistry and coveralls in Woodworking lessons. A full analysis of the clothing insulation in pupils would therefore require a year round survey and a survey for different lesson types. The former would be very time consuming and it is considered that the variation in time can be easily captured based on observations of clothing worn and by relating these observations to existing data (ISO 9920 2003). For the present paper it was considered relevant to look at variations in clothing insulation within a group of pupils and to look at the effect of specialised clothing.

For use in the heat balance equation, activity levels are expressed as metabolic rates, i.e. heat production in Watt or in Watt per square metre body surface area. A large amount of data on metabolic rates for various activities is available, and can be deduced from tables (ISO 8996 2004, Spitzer *et al.* 1982, Ainsworth *et al.* 1993). However these contain few ‘education related’ activities and what is available is almost exclusively for adults. Conversion of adult data to children e.g. based on body weight or surface area (Bouchard *et al.* 1983), can lead to substantial errors (Torun 1983). Alternatively an age related correction may be used (Torun 1989) or the FAO/WHO/UNU (WHO 1985) correction that is a sex specific basic metabolic rate multiplier. However all these corrections will inevitably lead to errors as they do not consider all relevant factors (weight, surface area etc). Hence there is a need to collect actual data for a variety of school activities.

In schools activity levels will vary with different lessons, and activity levels are often associated with the type of classroom. In the Netherlands three relevant classroom types were identified for this study in discussions with the ministry of education: 1. Theory rooms, for educational styles where no special learning or teaching materials are required 2. Practical rooms, which are specifically designed for practical lessons (Physical Education, Arts, Vocational skills etc) and 3. Combined theory-practical rooms, which are designed to allow use for both practical and theory lessons.

2. Methods

2.1 Schools, lessons and pupils

In order to obtain data relevant to schools, a number of different schools were approached and after consent of school management, teachers, parents and pupils metabolic rates were determined in the pupils during various lessons and clothing insulation was determined. Measurements were performed in five groups of pupils (total 96 for clothing, 81 for metabolic rate):

A. Primary school, level 6, age 9-10 year;

B. Primary school, level 7, age 10-11 year;

C. Junior vocational (technical) education (junior high school) age 13-16;

C* Same as C, but including protective coveralls for clothing insulation determination

D. Junior vocational education, advanced level (junior high school) age 13-16;

E. Senior vocational (technical) education, advanced level (senior high school) age 16-18.

The lessons that were studied for metabolic rate are listed in Table 1.

2.2 Activity level / metabolic rate

Several methods are available for determination of metabolic rate (for detailed description see ISO 8996 2004, Scrimshaw *et al.* 1996, Norgan 1996 and Müller and Bosy-Westphal 2003). The most accurate method for short (hour) activity periods is the measurement of metabolic gas exchange (Oxygen uptake, [$\dot{V}O_2$] and carbon dioxide production [$\dot{V}CO_2$]), followed in reliability by analyses of heart rate and finally various estimation methods using posture and movement analysis or simply looking up similar activities in tables (Havenith *et al.* 2002). The latter two, the table method and the estimation of metabolic rate based on posture and movement analyses (ISO 8996 2004) were considered not applicable, as these have not been validated in children.

The most accurate method, respiratory gas analysis, requires gas analyses equipment to be connected to the pupil during the activity. In some lessons this would interfere unacceptably with the freedom of movement. For this reason a variety of methods were applied (one per case).

2.2.1 *Oxylog*

The preferred equipment available in terms of a balance of freedom of movement and accuracy was a portable oxygen analyser (P.K.Morgan, Chatham, Kent) mounted on a small backpack frame with a data logger (total 4.5 kg). It was used for measurements where the pupil would move around in the classroom. It could also be used in a static situation, by putting it next to the pupil on a table or chair, so that the weight was not carried. Absolute precision for calculation of metabolic rate with this system is better than 5% (Louhevaara *et al.* 1985; Harrison *et al.* 1982). The system was calibrated with certified gas mixtures and a volume syringe. Some problems exist with this measurement system: 1-at low activity levels (especially in children) the respiratory flows are too low for proper function of the turbine flow meter; 2-in fast moves the inertia of the back pack will affect the activity; 3-the weight of the system will affect the metabolic rate significantly if it exceeds 10% of body weight (Hong *et al.* 2000).

2.2.2 Diaferometer

Given the problems with low respiratory flows at low activity levels, typically occurring in theory lessons in young children, a system was devised using a Diaferometer (Kipp & Zonen, Delft) gas analyser. This open circuit indirect calorimeter is normally used for accurate determinations of resting metabolic rates by analysing the gas contents of a fixed air volume it draws from the participant (Torun and Viteri 1981). In resting metabolism applications air is typically drawn from a hood that covers the persons head. In the present experiment, the system was connected by tubing to five individual children-size face masks simultaneously, and had a shunt to the room. The slight negative pressure produced in the face masks reduced the problems of leakage on expiration as well as effects of the valve system resistance. The expired air of the five pupils was mixed in the system and analysed. Metabolic rate was calculated using Weir's equation (Weir 1949), producing an average metabolic rate value for the five pupils. This system was only used in static classroom situations.

2.2.3 Heart rate analysis

Heart rate measurement for determination of metabolic rate is the most commonly employed method in children (Müller and Bosy-Westphal 2003). This method was shown to produce reliable results (within 10% of respiratory gas analysis value; Havenith 1987), but is limited to dynamic exercise as static work changes the heart rate-metabolic rate relationship (Bouchard and Trudeau 2007). For the present experiment it was used in those situations where fast movements were present (PE lessons), as an indirect measurement of metabolic rate. Heart rates (Polar Electro, Finland) were obtained during the lessons and these were later converted to metabolic rates using a calibration curve of heart rate versus metabolic rate that was obtained from each individual participant on a cycle ergometer. Pupils were allowed to get used to the equipment until they felt comfortable with it, before the measurement started. Metabolic rate measurements lasted 45 minutes to 1 hour.

2.3 Clothing insulation

Measurement of clothing insulation (ISO 9920 2003) was not practical, given high costs involved and the lack of thermal manikins of correct size. As alternative method, estimation of insulation values was considered. Using existing tables of insulation (ISO 9920 2003) was not considered valid, as these were all for adult sizes. Estimations using regression equations (McCullough *et al.* 1984) were also based on adult clothing, but as these were using physical measurements of the clothing ensembles it was decided that these could be adapted to use in children by scaling of the measurements. The equation used for the calculation of intrinsic insulation is:

$$I_{\mathrm{cl}} = 0.919 + 0.255 \cdot weight - 0.00874 \cdot BSA_0 - 0.0051 \cdot BSAC_1 \qquad \text{(clo)} \qquad (1)$$

$with:$

I_{cl} = intrinsic clothing insulation (clo)

$weight$ = clothing weight (kg) excluding shoes

BSA_0 = body surface area nude (%)

$BSAC_1$ = body surface area covered by one layer of clothing (%)

This equation calculates clothing insulation by assuming an insulation based on the weight for multi layer clothing and then subtracting insulation for nude and single layer areas. The surface areas are automatically scaled. It was decided to scale the clothing weight based on body surface area (A_D, Dubois and Dubois 1916), taking a 1.8 m^2 person as reference. Garment weights were determined during PE lessons when pupils had changed into PE-kit.

After the PE-lesson, the clothed pupils were photographed front and back, and these were used to analyse the size of uncovered and covered surface areas.

Summary statistics of the data were produced using SYSTAT (SYSTAT Inc 2004).

3. Results

The physical data on the participant groups and the results of the clothing measurements are presented in Table 2. The data measured related to metabolic rate are presented in Table 3. The three methods worked without complications in the different situations. The Diaferometer measurements took a short while for the participants to get used to (face mask), visible by an initial hyperventilation. However, after about 20 minutes data stabilised and respiratory exchange ratios returned to normal (Jones and Campbell 1982). With the Oxylog measurements problems can occur related to low respiratory minute volumes which affect flowmeter response. These problems were not observed at the high schools, while these problems were present when used at primary school level for static situations due to the low ventilatory volume of the young children. In such cases the data were excluded. In the Physical Education lessons, the Oxylog could not be applied due to its impact on the activity (physical size and weight) as well as for safety towards the wearer and other pupils. The calibrations for the Heart Rate method on the cycle ergometer functioned without problems and heart rates observed in the activities were high enough for the activity to be classified as dynamic exercise; a requirement for application of this method (Åstrand and Rodahl 1986). Clothing insulations were not significantly different between groups, except for group C* where the higher insulation was caused by the additional coverall.

4. Discussion

This study was a data gathering exercise with the main purpose of producing tabulated data on metabolic rates in school children in various lesson types. Such tabulated data exist for adults involved in a multitude of activities (Spitzer *et al*. 1982; ISO 8996 2004), but few were available for children and none for school activities. The adult data have been used for many years in climatic stress and thermal comfort assessments of workplaces and buildings (Havenith *et al.* 2002, Havenith 2004) and in the design phase of climate control systems. The metabolic rate is one of the six parameters needed as input into such calculations (the others being: air temperature, radiant temperature, relative humidity or water vapour pressure, air speed, and clothing insulation; Havenith 2004). Using the data produced in this study, rather than estimating data for children based on adult data, this work can now be expanded with improved validity to school environments.

A second area of application of metabolic rate tables is that of child nutrition. Children data were collected and published by various authors (e.g. Bandini *et al.* 2006, Spadano *et al.* 2003, 2005, Torun, 1989) and are used to calculate daily energy and nutritional requirements. Again, no school related data were available so far and these are provided in this study.

A second goal of the study was to provide more insight in the clothing 'behaviour' of the school children. For a full assessment a year round collection of data would be required, which would have been beyond the scope of this study. In addition, due to fashion changes, data might 'age' quickly. Nevertheless, it was deemed relevant to study clothing insulation even if it was just a snapshot in time. Data were gathered to look at variation of insulation within and between groups. So, even if absolute values may change over years, it was expected that the information on variation would remain valid.

4.1 Clothing Insulation

Results in Table 2 show that though a reasonable amount of variation is present within each group (CV=6-12%), the average insulation value is quite similar between groups (A to E, excl. C*; within 6% of overall mean). This can be explained by the high level of uniformity in the clothing worn. Though no school uniform exists in the Netherlands, the typical clothing is comprised of jeans, polo shirt or blouse, and sweater. These have similar covered body areas and will thus provide similar insulation, modulated by the clothing weight.

Wearing of special protective clothing (e.g. welder apron in relevant lessons) was avoided by pupils where possible. Only the coverall was worn systematically in practical lessons (woodworking, welding). In one school, about one third of pupils in several classes wore coats in the classroom. This appeared to have started as a protection against theft, but though measures were in force solving this problem the habit continued. As the functional need for wearing coats had disappeared, this habit may now be regarded as 'fashion'. For this reason, no coats were included in the clothing data collected. Absolute clothing insulation values range around 0.9 to 1 clo, which would be regarded as normal for office conditions in wintertime (ISO 7730 2005). As mentioned in the introduction, these data only provide a snapshot of the real values, but they do provide data on variation at a time when expected inter-individual variation is highest (winter). Absolute insulation values seem to be in line with values expected for adults in this time of year (ISO 7730 2005; ISO 9920 2003).

4.2 Metabolic rate

All three measurement methods (Diaferometer, Oxylog, and Heart Rate) were deemed appropriate for the specific application situations (ISO 8996 2004, Scrimshaw *et al.* 1996, Norgan 1996). Alternative methods were either not fit for the short periods investigated (doubly labelled water) or too inaccurate lacking proper reference data (observation analysis, actimeters). The observed values (Table 3) for theory rooms ranged from 52 to 88 $W.m^{-2}$. This includes one outlier, which was of an extremely nervous, fidgeting pupil (E-business administration). As this is considered exceptional this person was omitted from the dataset. The range then becomes 52 - 72 $W.m^{-2}$.

For the combined theory-practical rooms, similar ranges are observed, but at a higher absolute value (69-80 $W.m^{-2}$). This is clearly related to the different (higher) activity patterns in these rooms, where the students have more freedom to move around. For the practical rooms, the variation within lessons (between pupils in the same lesson) and between different lessons are both quite large. Between-lesson variation is directly related to content of the different lessons, affecting the average activity level of the group. The spread within a group in a single lesson on the other hand is representing the wider choice of the individual students to vary their activity/mobility levels within the same task. Typical range is between 59 and 121 $W.m^{-2}$ (excluding PE).

Values have been normalised (adjusted) by body surface area. Given the use in heat balance models for determination of thermal comfort, this is relevant to the application as input units for this are typically in $W.m^{-2}$. For calculation of surface area the Dubois and Dubois (1916) equation was used. It may be questioned whether this is valid for the current young groups. To study this, the surface area was also calculated using the theoretical model postulated by Wang and Hihara (2003). It was observed that this stayed within 1.5% of the Dubois and Dubois value. In comparison to other equations, including children's, Wang's equation stays within 2.5% for surface areas above 1 m^2. Given these low deviations, it was preferred to work with a single equation rather than having separate ones for different age groups.
In biology, standardisation or normalisation of data is typically performed based on body weight ($W.kg^{-1}$) and therefore this was also presented in Table 3.

Use of these types of scaling suggests that it may be possible to use adult data and convert them to the lower weight or surface area for young pupils. However substantial evidence exists that values from one age group should not be converted to other age groups using 'per unit of weight' data as the relation is not linear (Rogers *et al.* 1995). In addition, this non-linear relation between body weight and metabolic rate varies with the type of activity (Rogers *et al.* 1995; Norgan 1996). It is also highly likely that this is also true for the 'per unit of surface area' values, as the ratio of body surface area per unit of (muscle) mass changes dramatically with age.

Comparison of observed values with data for adults provided in ISO 8996 (2004) shows that theory class data are substantially below those for the adult value of 100 $W.m^{-2}$ for activity 'sitting quietly, light writing exercise'. The same is the case for combined theory-practical classes. For the practical classes, table values for adults for woodworking showed a range of 110 to 175 $W.m^{-2}$. Measured individual values in the present study ranged from 70 to 140 $W.m^{-2}$. This indicates that the school values are lower than would be expected from ISO 8996 (2004) data. In part this may be attributed to body size, giving lower values for children (they have a larger surface for their mass which could result in a lower metabolic rate per square meter). However for the older age groups (group D and E) body size is comparable to adults and values are still lower than those of ISO 8996 (2004). ISO 8996 data is very much based on workplace data however, which may result in a higher activity level than seen in the pupils.

For the measurements using the Diaferometer, it cannot be excluded that the equipment could have affected activity levels due to the constant connection of the facemask to a breathing tube which may have limited movement. However, according to teachers the activity levels observed were typical.

For children, the majority of available data in literature is based on 24 hour or longer heart rate recordings or measurements using doubly labelled water. These total energy expenditure data are summarised by Scrimshaw *et al*. (1996) and are presented as 24 hour averages. The values are 74 to 80 watts (approx. 3.3 $W.kg^{-1}$) for 6-8 year olds, 97 to 106 (approx. 2.45 $W.kg^{-1}$) watts for 10-12 year olds and 133 to 140 watts (approx. 2.15 $W.kg^{-1}$) for 14-16 year olds. This is substantially more than the resting metabolic rate (RMR; around 60 to 70% higher) and these averages are above the values observed in the theory lessons in the current study. The most likely explanation is a much higher energy expenditure during out of school hours that increases the average. The values observed in this experiment for theory lessons are higher than the RMR for the age group (Black *et al.* 1996).

Spadano *et al.* (2003) observed in 12 year old girls resting metabolic rates of 50 $W.m^{-2}$ (1.56 $W.kg^{-1}$; 69.9 watt) and 68.8 $W.m^{-2}$ (2.12 $W.kg^{-1}$; 95.3 watt) for sitting and 73.3 $W.m^{-2}$ (2.26 $W.kg^{-1}$; 101.6 watt) for standing in 12 year olds. This group falls between group B and C age- and size wise. Metabolic rates for the theory lessens of the current experiment are close to the sitting values observed by Spadano *et al.*, especially when considering the ‘per weight’ value, with the ‘per surface area’ values being lower in group B. Rogers *et al.* (1995), studying resting and walking in pre and circumpubertal children observed RMR’s of 59.7 $W.m^{-2}$ for the prepubertal children (59.7 W, 2.07 $W.kg^{-1}$, 28.8 kg, 8y old) and 52.9 $W.m^{-2}$ for the circumpubertal children (78.8W, 1.53 $W.kg^{-1}$, 12.8 years old, 51.5 kg).

The values for the present youngest group, which is a year older and has a higher weight than Roger *et al.*’s prepubertal group, seem a bit low when expressed as $W.m^{-2}$ or $W.kg^{-1}$, but in absolute terms the numbers seem right for the low activity level of theory lessons. For the current group C, slightly older than the circumpubertal children, values for the theory lessons are clearly higher than the RMR data from Rogers *et al.*

In summary, data for clothing insulation and metabolic rate were obtained for pupils of different age and in different lessons. Clothing insulation was found to be similar to that expected for adults in the same (winter) season, with minimal variation with age but substantial variation within the groups. Metabolic rate values, obtained through three different methods, were lower than would be expected from adult data, but are supported by other child data. For design of climate control systems this implies that adults values for clothing insulation can be used in calculations for children, but also that specific children values for metabolic rate are required, as these were lower (per unit of mass or surface area) than adult values. Based on the data obtained a higher comfort temperature for the children compared to adults is expected based on the lower metabolic rates observed in the school children.

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Table 1: Overview of measurement situations

Lessons #	Group		Description
Primary School:			
1	A	Language, assignment	Seated Activity, students work individually on worksheets
2	A	Writing task	Seated activity, pupils write story
3	A	Art	Seated activity, cutting and pasting with paper
4	B	drawing	Seated activity
5	B	calculus	Seated activity. Teacher explains. Pupils listen and follow material in book
Junior vocational (technical) education			
6	C	Physics/Science test	Seated activity, writing.
7	C	Physics/Science practical	Sitting and standing, walking through classroom to get material and talk to teacher and other pupils
8	C*	Woodworking, machining	Standing at woodworking machine, light manual work
9	C*	Woodworking, manual	Standing and sitting at workbench, light manual work
10	C*	Welding	Standing and sitting at workbench, light manual work
11	C	Physical Education	Cooper test
12	C	Physical Education	Volleyball, game explanation and play
Retail school (vocational education)			
13	D	Shopwindow decoration	Standing, walking, light manual work
14	E	Shopwindow decoration	Standing, walking, light manual work
15	D	Technical drawing	Sitting, light manual work
16	D	Typing Lessons	Sitting light manual work
17	D	Social Science	Sitting, Listening, Discussing
18	D	Administration	Sitting, Listening, Discussing, writing
19	E	Administration	Sitting, Listening, Discussing, writing
20	D	Arts	Sitting, Standing, working with paper materials
Senior vocational (technical) education			
21	E	Physics/Science practical	Sitting and standing, walking through classroom to get material and talk to teacher and other pupils
22	E	'Concrete' practical	Sitting, standing, walking, working with base materials for concrete production, light manual work
23	E	Business Administration	Seated Activity, students work individually on worksheets
24	E	Drawing, road and water management	Standing Activity, students work individually on drawing tables
25	E	'Asphalt' practical	Mostly theoretical; Seated activity.

Table 2, Mean (±SD) physical data and clothing parameters of participant groups used in determination of clothing insulation.

Group	*A*	*B*	*C*	*C**	*D*	*E*
N	27	23	21	21	13	12
Mass (kg)	36.0 ±5.9	38.3 ±6.1	50.9 ±11.1	50.9 ±11.1	58.4 ±8.2	72.8 ±6.5
Stature (cm)	147 ±7	153 ±6	164 ±9	164 ±9	173 ±8	186 ±5
Body surface area A_D (m^2)	1.23 ±0.11	1.29 ±0.12	1.53 ±0.18	1.53 ±0.18	1.69 ±0.12	1.96 ±0.10
Clothing weight (g)	965 ±193	1036 ±176	1179 ±214	1938 ±348	1144 ±192	1607 ±301
Clothing weight[1] (g)	1417 ±262	1448 ±233	1398 ±269	2314 ±451	1215 ±170	1478 ±285
BSA_O (%)	14.3 ±1.6	14.1 ±1.1	13.9 ±1.7	13.8 ±0.4	13.7 ±3.7	14.6 ±3.9
BSA_l (%)	36.0 ±7.2	36.2 ±6.6	42.2 ±13.8	2.1 ±0.3	41.3 ±15.9	33.0 ±6.9
I_{cl} (clo)	0.97 ±0.09	0.98 ±0.06	0.94 ±0.11	1.38 ±0.13	0.90 ±0.10	1.00 ±0.12
CV (=SD/mean, %)	9	6	12	9	11	12

BSA0 = nude body surface area; BSA1=body surface area with single clothing layer; weight=weight of clothing without shoes; weight1=clothing weight scaled for body surface area; CV= coefficient of variation in clothing insulation within group.

A. Primary school, level 6 (UK equivalent: year level 5), age 9-10 year;
B. Primary school, level 7 (UK equivalent: year level 6), age 10-11 year;
C. Junior vocational (technical) education (junior high school) age 13-16;
C* Same as C, but including protective coveralls for clothing insulation determination
D. Junior vocational education, advanced level (junior high school) age 13-16;
E. Senior vocational (technical) education, advanced level (senior high school) age 16-18.

Table 3: Data for measurement of metabolic rate. Room type: T=theory, P=Practical, C=combined. Method=manner in which metabolic rate was determined. A_D=body surface area; metabolic rate * = metabolic rate corrected for weight of equipment carried; #:SD is not present for diaferometer as whole group of 5 participants was measured connected together to the same analyser, giving a total oxygen uptake for the group that is then divided by 5.

		Group	n	Room type	Air Temperature (ºC)	method	Metabolic Rate (W)	sd	A_D (m^2)	Weight (kg)	Metabolic Rate ($W.kg^{-1}$)	Metabolic Rate ($W.m^{-2}$)	sd	Metabolic Rate* ($W.m^{-2}$)	sd
Primary school															
1	Language, assignment	A	5	T	18.4.	diaf	63	#	1.22	34.1	1.86	52	#	52	#
2	Writing task	A	5	T	19.5	diaf	68	#	1.29	38.1	1.79	53	#	53	#
3	Art	A	5	P	20.5	diaf	77	#	1.29	37.8	2.01	59	#	59	#
4	Drawing	B	5	T	21.5	diaf	79	#	1.27	36.5	2.15	62	#	62	#
5	Calculus	B	5	T	22	diaf	84	#	1.30	37.6	2.22	64	#	64	#
Junior vocational (technical) education															
6	Physics/Science test	C	4	T	22.8	oxyl	128	17	1.75	62.5	2.05	73	9	73	9
7	Physics/Science practical	C	3	C	20.1	oxyl	122	20	1.77	62.2	1.96	69	10	69	10
8	Woodworking, machining	C*	5	P	19.8	oxyl	214	53	1.66	59.8	3.58	129	28	121	28
9	Woodworking, manual	C*	4	P	18.1	oxyl	159	40	1.58	56.2	2.83	102	21	96	21
10	Welding	C*	3	P	17	oxyl	150	34	1.56	56.7	2.64	98	19	91	19
11	Physical education Cooper test	C	2	P	18	HR	242	279	1.53	50.0	4.84	158	161	158	161
12	Physical education volleyball game training	C	2	P	18	HR	334	157	1.67	60.7	5.50	200[1)]	91	200[1)]	91
Retail school (vocational education)															
13	Shopwindow decoration	D	2	P	20.8	oxyl	148	37	1.58	52.7	2.85	95	24	87	24
14	Shopwindow decoration	E	2	P	20.9	oxyl	203	45	1.89	68.5	2.98	108	24	102	24
15	Technical drawing	D	3	P	20.9	oxyl	131	25	1.72	61.0	2.17	77	15	77	15
16	Typing lesson	D	1	C	20.4	oxyl	134	9	1.75	62.8	2.15	77	5	77	5
17	Social science	D	3	T	20.4	oxyl	112	12	1.76	62.5	1.80	64	7	64	7

18	Administration	D	2	T	22.9	oxyl	98	16	1.70	60.2	1.64	58	9	58	9
19	Administration	E	2	T	20.4	oxyl	122	16	2.06	75.1	1.65	60	8	60	8
20	Arts	D	2	P	23.8	oxyl	157	29	1.70	58.4	2.69	93	17	93	17
Senior vocational (technical) education															
21	Physics/Science practical	E	4	C	21	oxyl	147	26	1.96	72.9	2.02	75	14	75	14
22	‘Concrete’ practical	E	4	P	11.3	oxyl	208	67	1.95	72.4	2.91	108	34	102	34
23	Business administration	E	2	T	22.3	oxyl	149	32	1.94	72.4	2.09	78	17	78	17
24	Drawing, road and water management	E	4	C	21.7	oxyl	167	35	2.08	75.2	2.21	80	17	80	17
25	‘Asphalt’ practical	E	4	P	19.3	oxyl	150	37	1.86	66.4	2.27	81	20	76	20

[1)] skewed distribution: M>300 $W.m^{-2}$ for 29% of time and M<80 $W.m^{-2}$ for 65% of time.