Daylighting in classrooms - the daylight factor as a performance criterion

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Presentation Preference: Poster

INTRODUCTION: Recent research has shown that environmental conditions in classrooms, and namely daylighting conditions, can influence students health, well-being and performance. In the last years several studies, dealing with the effects of environmental conditions in classrooms in the learning process, have been published (Winterbottom, & Wilkins, 2009; Barret, Zhang, Moffat, & Kobbacy, 2013).
The daylight factor (DF) is the most used parameter in the characterization and quantification of daylight in buildings. The DF at a point of a plane inside a room is defined as the ratio (expressed as a percentage) between the daylight illuminance at that point in the interior of the room and the simultaneous exterior horizontal global illuminance due to a hemisphere of a sky of known or assumed luminance distribution (usually, a CIE overcast sky luminance distribution is considered). The DF reflects the effectiveness of daylight penetration in a particular room or space. The exterior daylight conditions may vary, but the DF remains constant, since the interior illuminances change proportionally to the simultaneous changes in the exterior daylight conditions (Santos, 2006).

OBJECTIVES: Daylighting, like artificial lighting has advantages and disadvantages. However, taking into account the need for energy consumption reductions, we believe that, in Portugal, and in other Southern European countries, the conscious use of daylight in schools, new or rehabilitated, has a great potential for improving the comfort and the academic performance of users, contributing, simultaneously for the rational use of energy in buildings.
This paper presents the results of part of a research project, of a broader scope, which aims to assess, in an integrated way, several aspects that contribute to indoor environmental quality (IEQ) in classrooms. The project comprises 8 schools of different levels of education (from kindergarten to college level) located in urban and peri-urban areas of the city of Viseu (roughly in the centre of Portugal at approximately 500 m of altitude), installed in buildings of different types and dates of construction. A total of 32 classrooms are involved, with different orientations and sunlight exposures. The classrooms have an approximate average area of 50 m^2.

MATERIALS AND METHODS: This part of the project was held in December 2013 and January 2014 and included the assessment of the DF at 8 schools, comprising 2 rooms in each school, both located in the top floors. However, due to differences in the nebulosity conditions, there were only considered valid tests in 6 schools. Some of the characteristics of the classrooms used in the study are summarized in Table 1.

Table 1 – School and classroom building characterization

School Id	Level of education	Year of construction	Classroom Id	Window to floor ratio - WFR [%]	Window to wall ratio - WWR [%]
B	Lower secondary	1991	B3	9	20
			B4	12	26
C	Primary	2004	C3	17	31
			C4	17	31
D	Lower secondary	1968	D1	18	38
			D2	18	38
E	Primary and Lower secondary	1996	E3	12	20
			E4	13	27
F	Primary	1958	F2	17	32
			F4	17	33
G	Primary	2011	G3	18	33
			G4	17	32
			Average	15	30

From Table 1, it can be concluded that the window to floor ratio (WFR) and the window to wall ratio (WWR) have high average values. These high glazing areas can lead to overheating problems in the cooling season,

which can be avoided if appropriate shading devices (low solar factor with high visible transmittance) are also used. The types of shading devices used are as follows:
- in two of the schools (D and E) only interior shading devices are available;
- among the interior shading devices, the fabric rolling devices prevail (C, F and G);
- four of the schools have both interior and exterior shading devices (C, F, G and H);
- the use of fixed shading devices, horizontal or vertical tabs, is used by schools in various construction periods (schools A, C, and G).

The measurements were obtained using two luxmeters calibrated in the measuring range used (error + expanded uncertainty < 6%). The mesh comprised 25 measurement points spaced approximately 1 m, at a height coinciding with school desks (0.70 m). The measures were made in 5 rows each with 5 points.

RESULTS AND DISCUSSION: Under the same project, previous results showed that the levels of illuminance, with artificial lighting, in some rooms were not adequate (Pinto, Almeida, Pinho & Lemos, 2013). The present measurement campaign intended to measure the DF in order to assess the daylighting conditions. Figure 1 presents the results obtained in two of the classrooms.

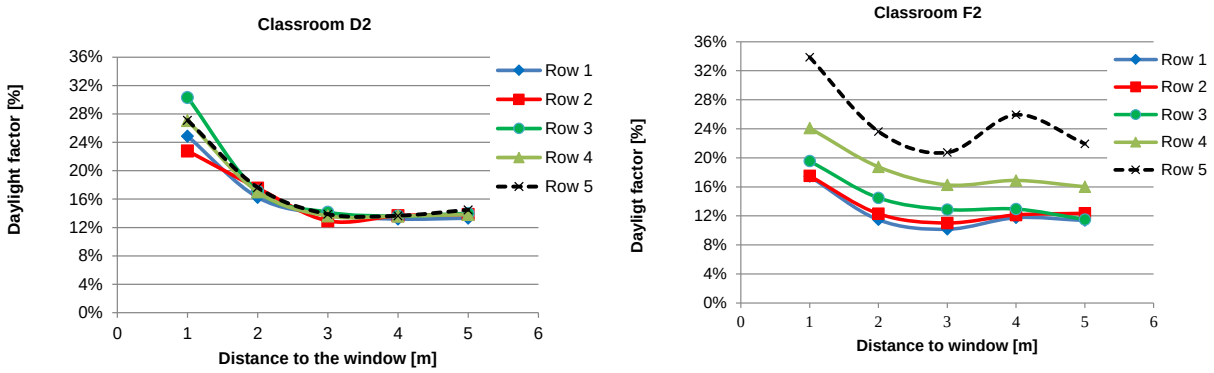

Figure 1 – Daylight factors for the classrooms D2 and F2

In Figure 1, the results in F2 classroom reflect the influence (in points 4 and 5) of large glazing areas facing each other (bilateral daylighting). In accordance with the high values of WWR and WFR, high ADF were to be expected. The values found for both the DF and for the average DF (ADF) are very high, well above the recommended (Santos, 2006).

The measured average daylight factor (ADF) in the different classrooms (without shading devices activated) varied from a maximum of 24 % in classroom B4 and a minimum of 8 % in classroom D1. The mean of the measured ADF were about 18%, which indicates that the quantity of daylight in the classrooms is substantial. As a consequence of these high ADF values, shading activation, particularly in overheating periods is also high. Glare problems due to large glazing areas also contribute to the frequent use of those shading devices, in order to minimize visual discomfort.

CONCLUSION: In Southern European regions, the DF can be used to define minimum requirements but not average conditions throughout the year. Therefore, the minimum daylighting natural lighting in classrooms studied denoting that are reasonable and the measurements previously performed with artificial lighting was not optimal. This project will serve to set guidelines with regard to natural lighting in architectural designs for new or rehabilitated schools.

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