211: Objective and Subjective Criteria Regarding the Effect of Sunlight and Daylight in Classrooms

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Abstract

Daylight and sunlight in classrooms are important parameters that affect health, emotions, and academic performance of the students as well as the energy consumption of the school building.
The present work is based on the general concept of Post Occupancy Evaluation Studies (POEs), combining both objective observations and subjective reporting by the occupants.
In order to extract useful information about the effect of daylighting strategies, a series of measurements and observations were carried out in twenty classrooms in three different towns in Greece. In this case, the objective observations consist of geometric assessment of the rooms and the fenestration, creation of a data basis of the shading devices and measurements of daylight levels combined with measurements of the transparency of the curtains used in the classrooms under examination. The subjective reporting derived from a short questionnaire used in nine of the twenty classrooms and from records of the teachers' comments.
The aim has been to identify the side effects of daylight use and sunlight penetration in classrooms, such as the annoying presence of sunlight on the desks and the extensive use of curtains, in order to overcome them in the future by means of innovative fenestration arrangements and design.

Keywords: Daylight, sunlight, classrooms, objective and subjective criteria

1. Introduction

Previous research on the use of daylight and sunlight in classrooms has shown that these parameters are closely related to issues like human performance and energy consumption of buildings [1],[2],[3],[4],[5].
Although older research had focused on the quantity of lighting in educational spaces, recent works prove that quality of lighting is at least as important as quantity [6], [7]. This shift from quantity to quality is also noticeable in the regulations developed in the 90's, especially in the UK and the USA, regarding the recommendations for daylighting in schools [6], [8]. For example, the CIBSE Lighting Guide 5 addresses issues like minimum maintained illuminance but also limiting glare rating, minimum colour rendering, specular reflections and control systems [9].
Studying the influence of natural light (daylight and sunlight) on students' response is not a trivial issue. As Wei Wu and Edward Ng concluded in their recent study [10], "*surveys of subjective response, physical measurements and statistical analysis are appropriate instruments for studying the relationships between daylighting quantity and quality in urban schools*".
The present work tried to exploit the above tools, in order to identify the side effects of daylight use and sunlight penetration in classrooms, such as the annoying presence of sunlight on the desks and the extensive use of curtains, in order to overcome them in the future by means of innovative fenestration arrangements and design.

2. Methodology

2.1 Post-Occupancy Evaluation (POE) studies

The term POE is being used for studies that employ a variety of methods for collecting information on the use of a building by its occupants as well as on its environmental performance [11].
Usually, POE studies consist of [11]:

- Objective observations of the physical environment
- Objective observations of the occupants behaviour
- Subjective reporting by the occupants

The aim of POE studies is to correlate the objective observations with the subjective reporting and come up with useful conclusions, which will lead to better design and retrofitting of buildings.
As far as daylighting is concerned, Task 21 of the International Energy Agency (IEA) suggests that

POE studies are useful measuring tools to study indoor daylit conditions [10].

2.2 The case study

The methodology of the current work aimed at assessing the general daylighting performance of existing Greek classrooms and also at investigating the way in which the occupants (students and teachers) handle and react to their daylit environment. In order to achieve these goals, the following methods were employed:

1) Objective observations of the classrooms: Photographs of the classrooms and the shading devices used, records of the geometrical characteristics of the classrooms as well as their orientation, and measurements of light levels and the transparency of curtains used.

2) Objective observations of the occupants' behaviour: observations have been focused on the use of curtains (as a means of glare and heat prevention) and also on the use of electric lights.

3) Subjective reporting: a questionnaire was handed to the students and the teachers were informally interviewed as well.

In particular, 9 classrooms of 5 schools in three different towns of northern Greece were chosen to be studied, so that the sample is representative of the schools in northern Greece (around 40° 00' N):

- 4 classrooms in 2 schools of Litochoro, a small town of 7.000 inhabitants.
- 3 classrooms in 1 school of Katerini, a town of 55.000 inhabitants.
- 2 classrooms in 2 schools of Thessaloniki, a town of about 700.000 inhabitants.

The selected schools are situated in urban contexts of different densities, so that external obstructions could be also investigated.

2.3 Objective observations

The photographs, plans and orientations of the 9 classrooms that were examined are shown in Figure 1.

As far as the shading devices are concerned (Figure2), the overall picture was disappointing, as none of the schools had properly designed shading systems for the classrooms (in a country with so many hours of sunshine). Except for the 1st Secondary School of Litochoro, which was built in about 1900, all the others were built in the '90s, when shading should have been seriously taken into consideration. In practice, curtains were the only shading devices in the classrooms under study.

The transparencies of the curtains used are shown in Figure 3. They were calculated by measuring the incoming light two times: once in front of the material and once behind it. It can be seen that most of them have a transparency of about 25-35%. In one case, though, the transparency was calculated as low as 0,5%!

The daylight levels were measured by using an EXTECH EasyView Light Meter (luxmeter) model EA30 with basic accuracy ⧖3%rdg and max resolution 0,01lux. The measurements were carried out under different weather conditions. Thus the results are not comparable and only served to form a general idea concerning the quantity of daylight in the classrooms. Almost all the spaces under study had the same ratio of glazing to floor area (1/20), complying, in this way, with the national regulations. When no curtains were used, the distribution of daylight factors was more or less the same in rooms with similar external obstacles.

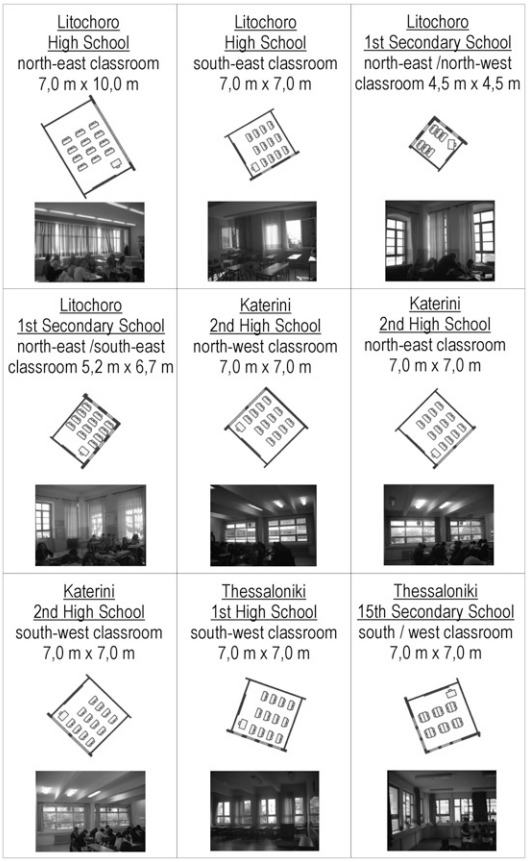

Fig. 1. The nine classrooms that were chosen to be studied. (North is towards the upper part of the page)

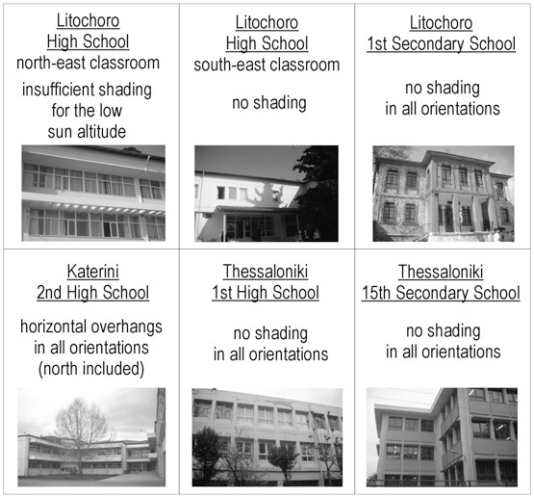

Fig. 2. The shading devices used in the schools under study.

However, in dense urban environment (like the case of the 1st High School of Thessaloniki) the

blocks of flats opposite to the classrooms significantly lowered the daylight levels in the spaces studied. This is clearly seen in Figure 4.

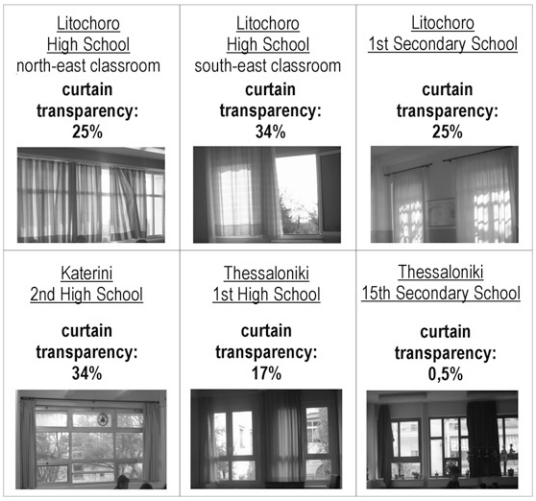

Fig. 3. The transparency of the curtains that were studied.

In the cases where shading was needed, the curtains had also a great effect on the internal daylight levels (Figure 4). This is due to the fact that they form an important "filter" between the external and internal environment.

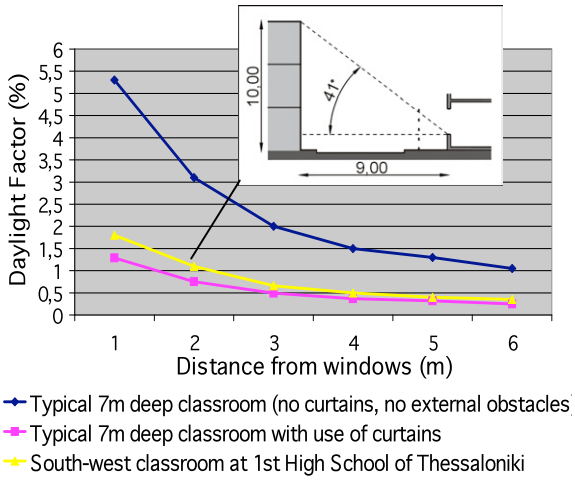

Fig. 4. Comparison between the daylight distributions of a) the typical case with no external obstacles and with no use of curtains b) the typical case with use of curtains (30% transparency) and c) a case with a medium external obstacle (1st High School of Thessaloniki).

The main conclusion concerning the daylight levels was that, except for the cases with external obstacles, the incoming light was sufficient but it was not well distributed. Especially when curtains were used to prevent heat gains and/or glare, the daylight levels fell too much at the back of the space. Also, from objective observations of occupants' behaviour it was concluded that the extensive use of curtains leaded to unjustifiable use of electric lights, even in sunny days. For this reason, the use of curtains was also investigated through the use of the questionnaire and the mini-interviews with the teachers.

2.4 Subjective reporting

As mentioned before, the subjective reporting consisted of a questionnaire that was filled in by the students as well as of informal mini-interviews with the teachers.

The aim of the questionnaire and the interviews has been to identify the side effects of daylight use and sunlight penetration in classrooms. The reaction of the occupants to undesirable sunlight was also investigated, as well as some other parameters of lighting in the classrooms.

The questionnaire was filled in by 203 students (of ages between 12 and 17 years old) in the 9 classrooms described above. It was composed of 10 questions, which are more or less related to the objective observations of the occupants' behaviour. It was chosen to use a simple and clear questionnaire in order to easily handle the results and to avoid tiring the students and the teachers.

The first three questions were introductory. The first one asked for the age, whereas the second asked whether the student was right or left-handed. In the third question the students were asked to point their seat on a classroom plan divided in six parts.

The next three questions (4-6) had to do with the presence of sunlight on the desks and on the blackboard. The questions and the corresponding answers are shown in Figures 5, 6 and 7.

It should be noted that, for the best presentation of the results, the first two diagrams (Figures 5 and 6), that refer to questions concerning the presence of sunlight on the desks, do not include the answers of the students who reported that no sunlight falls on their desk. (The number of the students with no sunlight on their desks represents the 36% of the total).

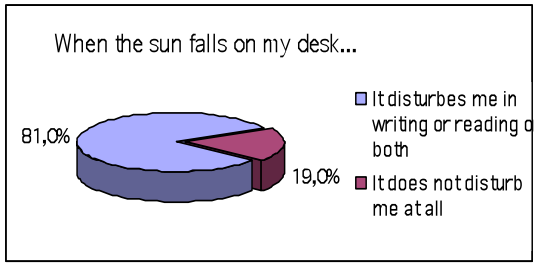

Fig. 5. The answers that express the disturbance caused by the direct sunlight on the desks.

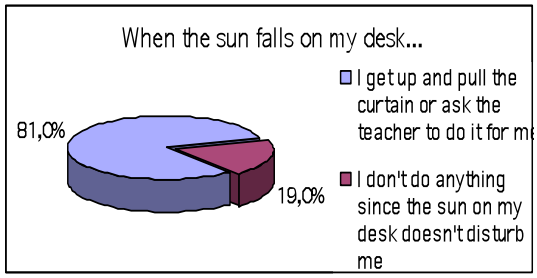

Fig. 6. The answers that express the reaction of the students to direct sunlight on the desks.

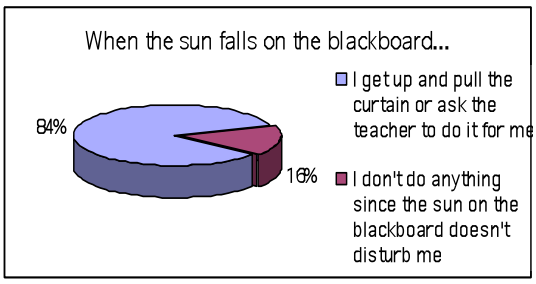

Fig. 7. The answers that express the disturbance caused by the direct sunlight on the blackboard.

From the above figures it emerges that sunlight falling on the desks is disturbing for a large number of students (81%) and as a reaction students pull the curtain in order to avoid it. The same, more or less, reactions correspond to the case when sunlight falls on the blackboard (84% of the students use the curtain to avoid the sun). These remarks totally agree with the comments made by the teachers during the informal mini-interviews.

The next questions referred to the students' opinion about a) the quantity of daylight falling on their desks, b) the quantity of daylight in the classroom and c) the electric lights. The results are shown in Figures 8, 9 and 10 respectively.

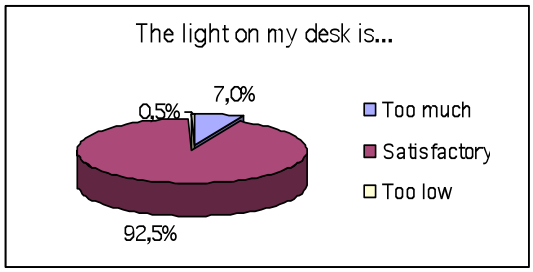

Fig. 8. The answers referring to the quantity of light on the desks.

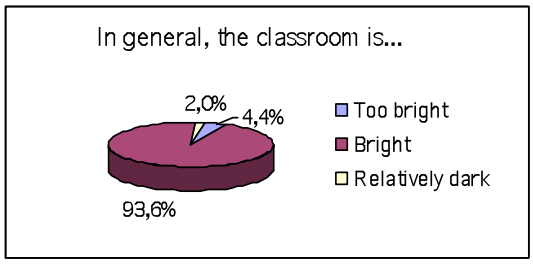

Fig. 9. The answers referring to the perception of brightness of the classroom.

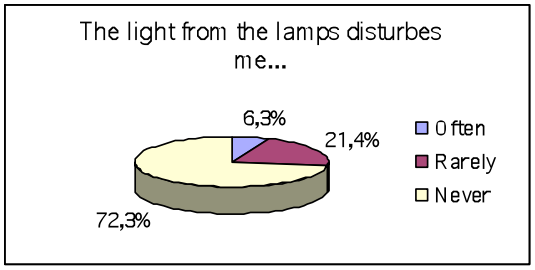

Fig. 10. The answers that express the disturbance caused by the electric lights.

The answers referring to the amount of light on the desks and the perception of brightness of the classroom (figures 8 and 9) were somehow expected since the electric lights were on, in order to provide enough light at the back of the space. In all classrooms the electric lights were not grouped in any way, which means that they were all together switched on or off. When they are all on, in order to light up the darkest parts, the space closer to the windows was overwhelmingly lit, a fact that could have been seen in the answers of the students (in relation to their seats). No such results were obtained, though, which may be due to the fact that the students of that age are not very familiar with the idea of "light quantity".

As far as electric lights are concerned (Figure 10), it emerged that they almost never annoy the students. From discussion it was concluded that sometimes the students are disturbed by the noise that fluorescent lamps produce.

Another issue that emerged from the informal mini-interviews is that the new whiteboards cause undesirable reflections, in contrast with the older matt and dark blackboards.

Also, it emerged that the age as well as the fact of being right or left-handed did not have an impact on the students' answers. Furthermore, no correlation was found between the place of the seats and any of the answers (except of the fact that the students in the deeper parts of the rooms stated that there was no sun falling on their desks). The absence of correlation was probably due to the fact that electric lights were on, thus creating an evenly lit environment.

All the above mentioned questions were closed ones, aiming at achieving straightforward quantification, easy process and simplification of comparisons. In order to obtain greater validity, the final (10th) question of the questionnaire was an open one. It specifically asked whether there was something else negative or positive that he/she would like to comment, regarding the lighting in the classroom. Unfortunately there were scarcely any answers to this question, which means that either the students were covered by the questions already asked or that they were not very familiar with or keen on the subject.

In essence, one of the most important results is the fact that most students were disturbed by the sunlight on their desks or on the blackboard and used the curtains to avoid it (since there was no other shading system). It is worth noticing here that these findings agree with Ne'eman et al.'s work [12] on 6 schools in the U.K. (89 completed questionnaires by teachers). In their study, many teachers remarked that blinds and curtains were used against the sun purely for the children's benefit. The teacher could work quite happily in sun conditions – often because a position by the blackboard meant a good distance from the windows – but the children complained of discomfort, both thermal and visual. In another work, Ne'eman et al [13] concluded that *"the more freedom the occupants have to change the direction of their view and position in relation to*

the sun, the less negative may the effect of the sun be". Another very interesting conclusion was that "*the favoured qualities of the sun - its psychological effects of cheering the teacher up or making the children work better or the room look more pleasant – all come from* sight *of sunlight rather than the physical* touch *of sunshine on the body. Its discomforts come from the physical touch of sunshine – either shining into the eyes or onto the body"* [12].

From the informal interviews with the teachers in the 9 classrooms under study it emerged that the curtains were drawn not only when the sun fell on the working plane or on the blackboard, but also on cloudy days, just because nobody pulled them aside or in order to achieve more privacy. As a result, according to the teachers, the electric lights are on, most of the times. Although it did not emerge from the study, it should be mentioned that when curtains are drawn, difficulties with ventilation also occur.

The conclusions from the subjective reporting are correlated to the objective observations in that the lack of properly designed shading devices leads to extensive use of curtains, which, in turn, significantly decreases the internal daylight levels.

3. Conclusions

This study has taken a step in the direction of studying the quality of lighting in classrooms. This was done by employing different methods, objective observations and subjective reporting, in order to identify the side effects of daylight use and sunlight penetration in classrooms, such as the annoying presence of sunlight on the desks and the extensive use of curtains.

From the objective observations it emerged that:

- There were no correctly designed shading devices in any of the schools under study.
- Except for the cases with external obstacles, the incoming light was sufficient but it was not well distributed.
- In dense urban environments the blocks of flats opposite to the classrooms significantly lower the internal daylight levels.
- In sunny days, when curtains were used to prevent heat gains and/or glare, the daylight levels fell so much that electric lights were needed.

The subjective reporting showed that:

- Sunlight falling on the desks or on the blackboard is disturbing for the majority of students and that the ones that are disturbed pull the curtain to avoid the sun.
- The amount of light, natural and electric, on the desks and in the classrooms in general, seems to satisfy both the students and the teachers.
- The electric lights do not usually disturb or create any problems.

For the above conclusions to be more robust, and in order to achieve greater reliability, a larger sample of both buildings and occupants would be needed. Further work could also include areas in Greece with substantial differences as far as climatic conditions are concerned.

The conclusions of the current study can be used for the design of more efficient innovative daylighting systems for classrooms. In particular, based on the experience gained from this work, research should be oriented towards replacing the curtains with new arrangements that will:

- provide sufficient shading
- protect from glare
- evenly distribute daylight in the space
- not significantly decrease daylight levels on the working plane

The current work also reminds us that in designing the fenestration arrangements and daylighting systems in general, one must not neglect the human factor, and in particular the reaction of occupants to direct sunlight.

4. Acknowledgments

The authors would like to thank all the students and teachers that were involved in the subjective reporting.

5. References

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