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Viewing conditions on worktops when writing in a hall lighted by electric lamps

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Abstract: Multimedia projectors are used increasingly in academic centres and ensuring good visibility of the screen requires the limiting of light in classrooms. The purpose of the paper was to evaluate the quality of artificial general lighting on worktops used for writing in a didactic room. It was measured with full lighting and for three variants (degrees) of lighting dimmed during the display of a multimedia presentation. There were 24 measuring points set in the room and the intensity of the lighting was measured with a luxmeter. After setting the potentiometer half-way between the maximum and minimum level of lighting, which switched on automatically once the projector was on, the brightness at most of the measuring points was less than the required 500 Lx. With the minimum lighting for this mode, the visual discomfort was recorded in the students' working areas. Therefore, a conclusion was made that didactic spaces with multimedia projectors should be additionally equipped with task lighting such as lamps fixed on every worktop used for note taking. Introducing smart lighting systems which facilitate dynamic collaboration of general and local lighting would help to improve viewing conditions in the room and reduce energy consumption of electric lamps.

Keywords: artificial lighting intensity, viewing conditions on desktops, didactic room, multimedia projection

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Introduction

Life in industrialized societies means living mainly inside buildings (Stevens & Rea, 2001). Interiors designed for people must have a suitable microclimate and one of the primary aspects of comfort in a room is the visual comfort (Motamed

et al., 2017). Visual comfort is crucial and as research and observations of human behaviours and the biological effects of light have revealed, artificial or natural light has an important role of maintaining physiological and mental balance in the human body (Paroncini et al., 2007). Lighting deeply affects health, well-being (Bommel, 2006; Turner et al., 2010), vigilance and even the quality of sleep (Bommel, 2006). For this reason, the influence of interior lighting on the visual comfort of residents and eye health has been studied (Hwang & Kim, 2010) and the types of diseases which may result from light deficiency have been identified (Turner et al., 2010). Scientific tests have shown that greater intensities of light quickly increase satisfaction with the lighting conditions and reduce the struggle and effort needed to perform different activities (McGuinness et al., 1983). On the contrary, lower intensities of lighting may, for example, result in a varied quality of performance and evaluation of tasks by people of different ages (McGuinness & Boyce, 1984).

Indoor lighting, both natural and artificial, is designed to address not only the general visual needs of residents but also, with consideration to specific tasks they are to perform in the space (Webb, 2006). Light intensity (brightness) and the distribution of lights in the work space and surrounding areas have a great influence on the performance of a task (Alrubaih et al., 2013). In the case of work environments, good lighting is beneficial not only for employee health and well-being but it also results in greater efficiency, less errors, greater safety and less absences from work (Bommel & Beld, 2004). Activities, performed on worktops in didactic rooms, involve writing and drawing. For this reason, the system of lighting in universities and other educational institutions is critical as it affects the learning environment (Hui & Cheng, 2008). Effective teaching and learning in higher educational institutions is often limited due to the characteristics of the available learning spaces (Cannon & Kapelis, 1972). In academic centres, more and more often multimedia projectors are being used. Images are usually displayed on a white screen located above or next to traditional boards. Ensuring good visibility of the information displayed requires less intense lighting in the room, which consequently affects the visual comfort of students while they are taking notes. This is due to the intensity of light in their workspaces being possibly insufficient. In order to ensure better control of the brightness of the general lighting, rooms adapted for multimedia presentations have no windows and are lighted with artificial light. Despite objections regarding its influence on the health, this solution has some advantages. Artificial light is more stable and easier to control than daylight (Costanzo et al., 2017), and a lack of windows reduces light pollution from residual light, now one of the most rapidly growing problems of environmental degradation (Falchi et al., 2011).

Ensuring proper viewing conditions in a room should be considered alongside pro-ecological solutions and with the view to minimize the energy necessary to power lamps as part of the strategy of sustainable development in construction.

The purpose of this paper was to evaluate the quality of artificial general lighting on worktops used for writing in a didactic room. It was measured with full

lighting and for three variants (degrees) of lights dimmed during the display of a multimedia presentation.

1. Materials and methods

Distribution of light intensity was measured in a windowless hall, the horizontal cross-section of which is shown in Figure 1. Room number L323, with seats set in a theater-like manner (Fig. 2), is located in the didactic-administrative building on the University of Bielsko-Biala campus. The hall has 110 seats, 10 in each of the eleven ascending rows positioned parallel to the projection screen. The height of the room at the presenter's end, where the screen was fixed, was 4.75 m, while at the rear row of seats, it was 3.85 m. Single folded worktops were mounted at 0.77 m from the floor. Artificial lighting in the room consisted of 56 compact fluorescent lamps with the wattage of 26 W, luminous flux of 1800 Lm, color $T = 4000$ K, general Color Rendering Index R of 80-89 and an average life of 10 000 h. Electric lamps were installed in fixtures built into the ceiling, spaced in seven rows, 8 lamps in each row.

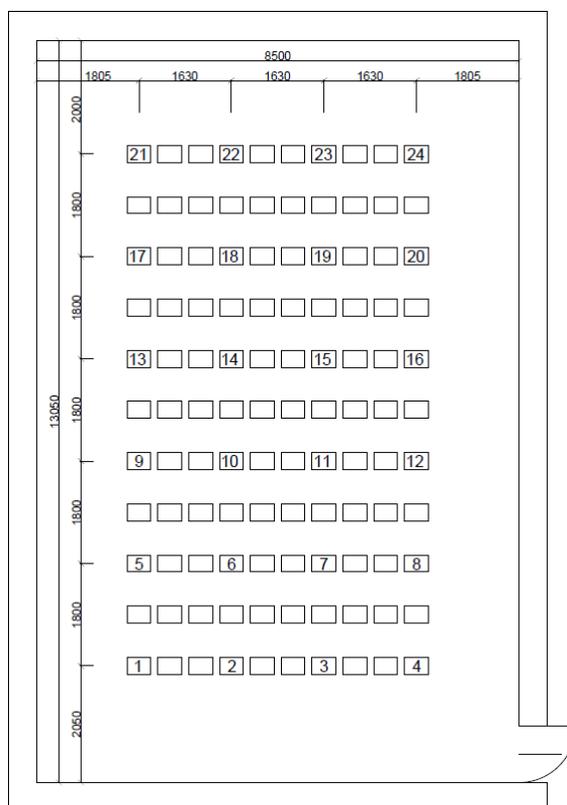


Fig. 1. Scheme of the didactic room with marked measuring stations where general lighting was measured (*own research*)



Fig. 2. The auditorium with the theatrical arrangement of seats, in which lectures are given in various lighting conditions (*own photo*)

The general lighting was measured at 24 measuring stations located in every third seat in all odd rows. The brightness of the artificial lighting was measured within the workspace used by the students, sliding worktops that served as work stations during note taking or drawing. The level of visual comfort was analysed for four lighting options: full lighting of the hall and with three variants of reduced lighting during the display of a multimedia presentation: maximum, half of the maximum and minimum lighting. The difference between any lighting options used during presentation and full lighting involved automatic switching-off of all lamps in the first row and two middle lamps in the second row. These were the lamps located directly in front of the projector, which is shown in Figure 3.

The brightness at the students' workstations was measured using a MASTECH MS6612 luxmeter according to the relevant standard (PN-EN 12464-1:2012). Based on the standard, we assumed that the minimum light intensity in a lecture room is 500 Lx, whereas, during the drawing up the technical drawing, it should amount up to 750 Lx. The photometric value was recorded in such manner that the person operating the luxmeter did not obstruct the projector. For every measuring point, the measured result for the general lighting was the mean value from three measurements shown by the luxmeter display. Before the measuring device was activated, we checked if its sensor was clean and once it was switched on, we checked if the indicator showed zero with the sensor covered.



Fig. 3. All lamps in the first row and two middle lamps in the second row switched off in the case of lighting activated by controller during multimedia presentation (*own photo*)

The air temperature was also determined empirically and it was compatible with the requirements set by the luxmeter manufacturer. As the light came from the discharge lamps, the measurements began 30 minutes after the lighting in the room had been switched on.

2. Results and discussion

Figure 4 presents a graph of general lighting intensity measured on the students' worktops in a fully lit room. This is only possible when no presentation is displayed on the screen. The value of general light intensity was only less than the required minimum of 500 Lx at two measuring stations: 21 and 24. At other measuring points the proper visual conditions were met and the mean brightness was 670 Lx. However, we did notice that the brightness decreases visibly at the worktops located on the outboard seats (measuring points number 1, 4, 5, 8, 9, 12, 13, 16, 17, 19, 20, 21 and 24) compared to those in the middle section of the room. This is due to the light reaching the student working area from only one side, from the right or left. We also noticed the lower intensity of lighting in the last row where the middle worktops provided less favourable viewing conditions than the outboard worktops in other rows.

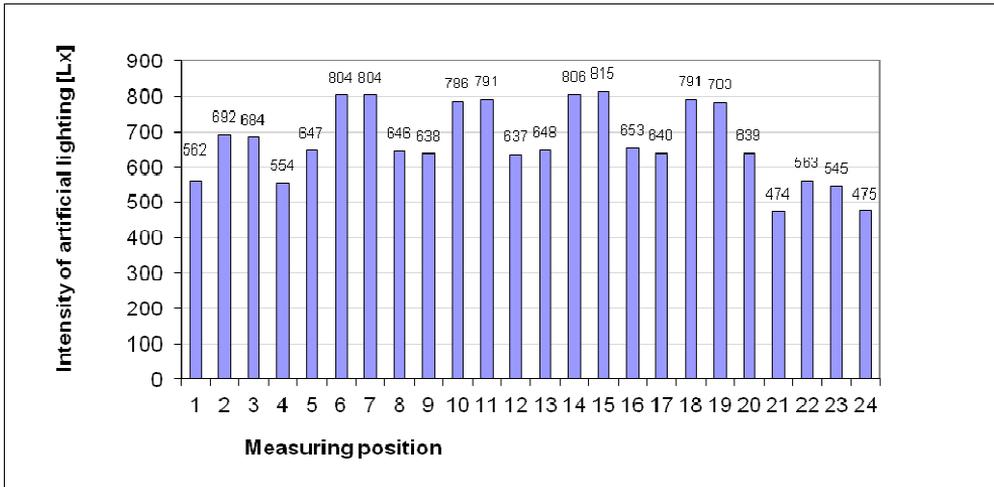


Fig. 4. General lighting intensity at worktops fixed on seats in the subsequent ascending rows with full artificial lighting (*own research*)

Figure 5 shows a graph of the general lighting intensity measured on the worktops with the lights in the presentation mode and set on its maximum value by the controller. The average value of this photometric value from the 24 measuring points was 584 Lx, which was still higher than the minimum of 500 Lx. However, we cannot evaluate the viewing conditions based only on the average brightness measured in a large didactic room with many seats located differently: in the middle of the room, by the side pathways, by the screen and in the corners. As a result of switching off all the lamps in the first row and two middle rows, which was necessary to ensure better visibility during the multimedia presentation, the measuring stations 1-4 (first row) recorded much lower lighting intensity than the required 500 Lx. At only 268, 324, 313 and 262 Lx. In addition, the measurements at the outboard stations (by the pathways) in the next row (third) and the last row, stations 5, 8, 21 and 24, confirmed visual discomfort in these places. This was because the locations did not meet the standard of the proper lighting needed during note taking, as the brightness was only 469, 474, 492 and 493 Lx, respectively. With both, full lighting when the projector was not used and the lighting during the presentation, the visual comfort on the central worktops was noticeably higher and the brightness at measuring point 15 was as high as 828 Lx. Scientific publications point out that, at present, many educational processes take place in artificial environments and it is necessary for the teachers to be aware of lighting conditions in the rooms they use (Kevan & Howes, 1980). According to authors, they should inform students how the light is distributed in the room and encourage people with weaker eyesight to take seats in the central part of the room.

The graph of the brightness at certain worktops when the electric lamps were on in the presentation mode with the potentiometer set half-way between the maximum and the minimum, is presented in Figure 6.

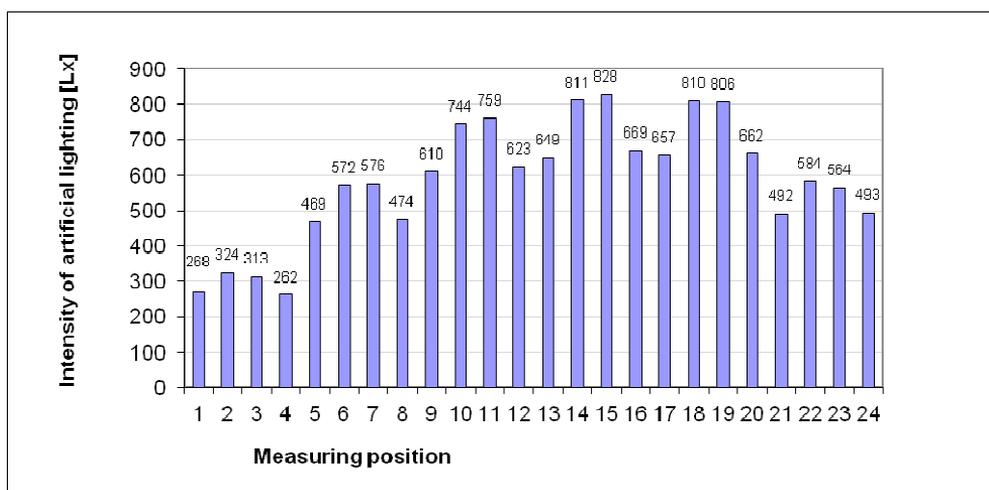


Fig. 5. General lighting intensity at worktops fixed to seats located on the subsequent height levels in the room during a presentation and with maximum artificial light (*own research*)

In this case, the average lighting intensity was 482 Lx. In more than half (13 out of the 24 stations) the brightness was unsatisfactory, below 500 Lx. During the investigation in this configuration, the light intensity was also visibly higher for the centrally located worktops as compared to the outboard ones, and lower in the first row. It is clear that delivering lectures in such conditions, does not ensure full visual note taking comfort and teaching activities can only consist of screen observation.

There is therefore a conflict of interests, improved visibility of, and the ability to discern details displayed on the screen enforces the reduction of light in the students' workspace. This situation is inevitable in a didactic room with only general lighting. Thus, lecturers must be aware of this and should not expect students to take notes in such conditions. A solution to eliminate visual discomfort during a presentation, when general lighting is limited and viewing conditions are poor, might be by using task lighting, such as lamps (e.g. LED) fixed to every worktop. The individual lighting points could be controlled automatically, switching on when a multimedia presentation begins and intensifying as the general lighting in the room is dimmed. Such intelligent systems which combine heterogeneous lighting technologies change the intensity of general or task lighting in order to ensure higher visual comfort in the room (Higuera et al., 2015). This should be considered as the 'greening' of the teaching space. With the application of task lighting, such a solution would reduce the general lighting by a maximum. This would be in line with the strategy of saving energy consumption (Dubois & Blomsterberg, 2011), as about 20% of electric energy consumed in the world is used for lighting (Görgülü & Ekren, 2013). In one study conducted by independent authors, using task lighting combined with dimmable general lighting saved as much as 59% energy (Xu et al., 2017), therefore, the economic dimension of using this type of lighting installation should also be emphasized.

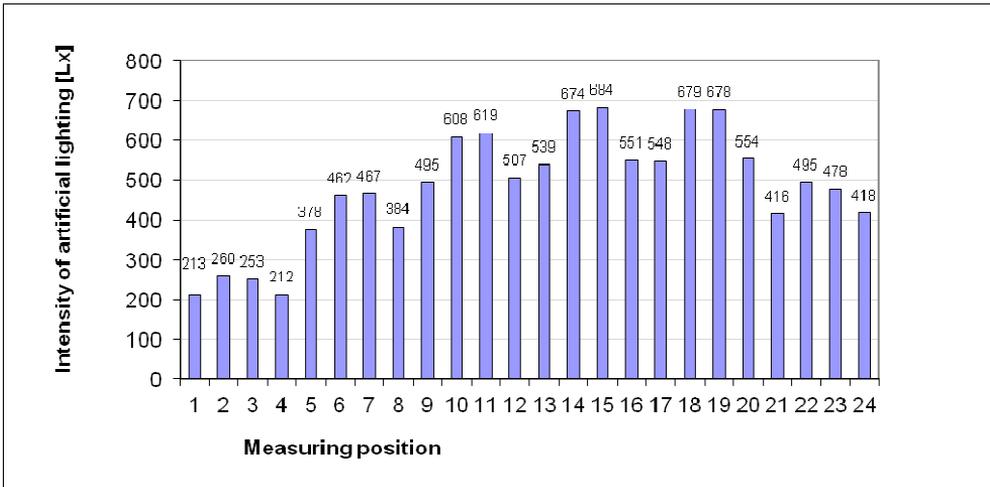


Fig. 6. General lighting intensity on worktops fixed to seats located at subsequent height levels in the room during presentation and with half of the maximum artificial light (*own research*)

Figure 7 shows the graph of the general lighting intensity measured at the worktops when the general light was in the presentation mode and was set to “minimum” (when the lamps were maximally dimmed). In this case, the average value of the artificial lighting intensity was only 60 Lx. As we can see, this value was much lower than the minimum acceptable brightness of 500 Lx necessary for note taking. The brightness did not exceed 90 Lx at any of the measuring points. As expected, brightness measured for the centrally located worktops as compared to the outboard ones was higher, and in the first row, where the lamps were switched off completely, the viewing conditions were much more adverse than in other rows.

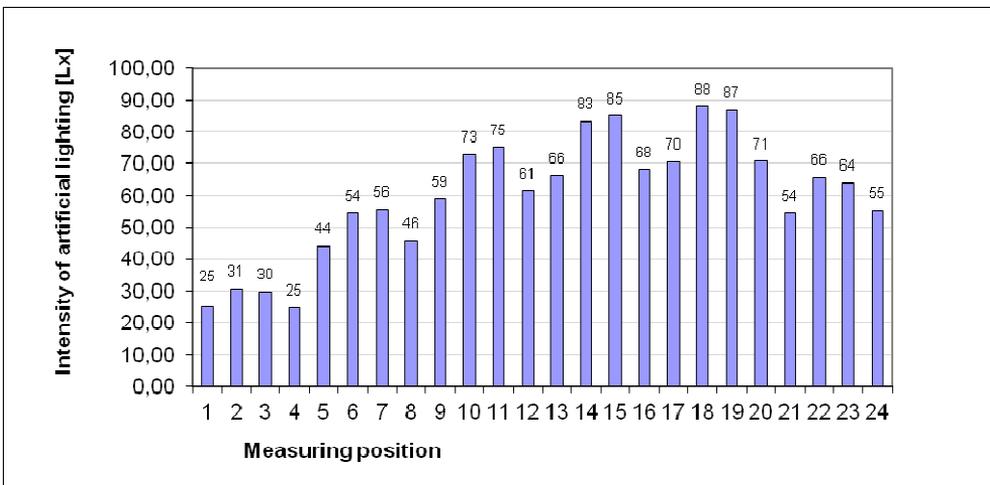


Fig. 7. General lighting intensity on worktops fixed to seats located at the subsequent height levels in the room during presentation and with minimum artificial light (*own research*)

During lectures in such environmental conditions, it is only possible to perceive information from the multimedia projector without being able to record it.

The results of the study suggest that urgent changes are needed in designing lighting in didactic rooms where multimedia presentations are displayed. Other researchers confirm the opinion of the authors, formulating the conclusion that with the increasing demands regarding the improvement of physical conditions in university facilities, lighting systems require urgent upgrading (Hui & Cheng, 2008). New approaches to lighting spaces used by people is also connected with a discovery in 2002 of the retinal ganglion cell in the eye and subsequent studies into the biological effects of lighting, which imply, that the principles for designing good and healthy lighting systems are, to some extent, different from the conventional methods applied (Bommel & Beld, 2004). Dynamic lighting systems could meet these challenges (Bommel, 2006). Electric lighting used at present may contribute to circadian rhythm disorders which, in turn, may cause endocrine disorders (Stevens & Rea, 2001).

There is some difficulty in comparing our results and the results presented in other reports. Despite the detailed analysis of the literature, the authors did not find publications addressing the problem of viewing conditions on worktops during dimmed general lighting in a room where multimedia presentations were displayed. There were other experiments performed, in rooms with artificial photo-climate where, for example, brightness for three different modes of lighting was studied: with recessed luminaires (general lighting), floor lamps (indirect lighting) and desk lamps (task lighting) (Borisuit et al., 2010). As for didactic spaces, there are studies into the influence of contrasts from eighteen substantially different systems on vision ability during the performance of visual tasks (Sampson, 1970). In schools in Great Britain, discomfort during task performance through glare, and imperceptible 100 Hz flicker from fluorescent lighting was studied (Winterbottom & Wilkins, 2009). In Bursa (Turkey), user satisfaction, including visual comfort, regarding the quality of the environment in university buildings was investigated (Erbil & Sezer 2016). However, these were survey not instrumental studies.

It is believed that architects, users, teachers and students may contribute to the decisions regarding the physical conditions of delivering knowledge, teacher-student interactions and other educational activities seen as desirable in higher education (Cannon & Kapelis, 1972). That is why, by presenting the results of their studies, the authors, an academic teacher and a student, intend to contribute to changes in the design of lighting systems in didactic rooms where multimedia presentations are displayed.

Observations and conclusions

The investigation into the intensity of artificial general lighting on worktops used by students in a didactic room led to the following observations and conclusions:

A. Observations:

1. The intensity of general artificial lighting in the room when the projector is off met the standards. At every measuring point its value was more than 500 Lx.
2. With maximum lighting provided during the operation of the projector, visual discomfort was recorded in the first row. The lamps located above the row switched off automatically and the brightness was less than 500 Lx at four corner measuring points located in the room.
3. With lighting set half-way between the maximum and the minimum, the lighting intensity on the level of student worktops was insufficient at most measuring points and its average value for the whole room was 482 Lx. This means that during lectures, students can only process information from a multimedia projector without taking notes.
4. With the minimal lighting possible during a presentation display, the brightness in the room was very low and did not exceed 90 Lx, making it impossible to save information in such conditions.
5. In every lighting mode the visual conditions at the worktops used for writing or drawing, fixed to the outboard seats were less favourable than in the central part of the room.

B. Conclusions:

1. Delivering lectures in a dimmed room, using a multimedia projector which displays images on a large screen increases visual discomfort of students because the general lighting in the room is dimmed.
2. Considering the ecological quality of the teaching space, an opinion can be formulated that the most favourable lighting solution in a windowless room during multimedia presentations and note taking is to combine the general lighting with lamps at every worktop.
3. We encourage designers of electric light installations in didactic rooms with projectors and screens to introduce smart lighting systems which would change adequately the intensity of general or task light to improve the visual comfort in the room. Such systems would be in line with the strategy of reducing energy consumption in artificially lit rooms.

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