Daylight appraisal classes for architecture students

A questionnaire combined with a practical assessment for the educational training recommendations

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ABSTRACT: The main objectives of this article are: (i) to present the relations between architecture students' subjective assessment of daylight in classrooms and the objective evaluation of daylit conditions using daylight simulations tools, (ii) to formulate guidelines and recommendations on daylight appraisal methods and tools which may be useful in architectural training. The methodology used includes an evaluation of the results of the direct questionnaire and the computational simulations of the observed conditions.
One hundred ninety-four architecture students form three different universities in Poland assessed daylight in 13 different classrooms. The questionnaire aimed to investigate relationships between daylight subjective assessment, students' perception and daylight knowledge. This paper focuses only on the results of the subjective appraisal of daylit interior spaces and the objective evaluation of the investigated conditions.
The simulations of Daylight Factor and Daylight Autonomy were carried out using various available software and the available climate and weather data (for DA).
The key findings of the study are:
Daylight appraisal part: (i) Daylight factor simulations results correspond with subjective students' assessments of daylight sufficiency within the rooms for eight out of 13 cases. (ii) The were no significant correlations found between the mean illuminances values and the subjective students' appraisals of daylight. The subjective description of daylight within the investigated classrooms was similar (medium) for all the sessions. (iii) The subjective perception of uniformity for task illumination was rated by observers as a medium, while the mean illuminance levels varied from 61 to 460 lx.
Architectural training part: (iv) The use of advanced computer daylight simulations tools supports educational activities and aids architectural design, only if the students can comprehend the obtained results (v) Available informative packages should cover contemporary analysis daylight tools.
KEYWORDS: Architecture, Daylighting, Education, Simulations

1. INTRODUCTION

A comprehension of daylight understood as a visible part of global solar radiation and its role within the built environment differs among professions [1]. Diurnal and seasonal variations of daylight plus disparities in its provision related to geographical, and climatic characteristics make day-lit spaces appraisal challenging. Description and parametrization of daylight dynamics and its image-forming and non-image-forming effects results in a number of various metrics and assessment methods. The differences in approaches to daylight parametrisation are noticeable during the ongoing discourse on daylight indices, standards [2,3] and educational curricula contents.

A correlation between building masses and perception of daylight is often described in various texts [4,5]. Although daylight provision within a space accounts for a substantial part for any architectural and urban planning project, daylight education is often not a part of the architectural training [6]. To change it a few daylight educational dissemination initiatives have been started by the CIE and DLA or the IEA task 51, subtask D [7].

This paper aims to formulate guidelines and recommendations on daylight appraisal methods and tools for architectural training in the context of Polish architectural education. The results are based on the direct questionnaire combined with the daylit appraisal task, which had been carried out for four years involving 194 architectural students. To illustrate the relationship between the subjective assessments and an objective evaluation of given daylight conditions the students were asked to appraise and reflect upon their perception of daylighting. Then, the students' appraisal results were compared with the results of simulations of Daylight Factor (DF), Spatial Daylight Autonomy (sDA) and daylight illuminance. The summary of the results comparison are:

- Daylight factor simulations results reflect well with subjective students' assessments of daylight within the rooms.
- The subjective perception of daylight was rated by observers as medium, while the simulations illuminance levels were 61 - 460 lx.
- In classrooms with high DA values the subjective students' appraisals mirror the simulations results. However, in cases with low results of DA values, subjective responses do not support the simulation results.

The results presented in this paper may help to formulate proposals for the daylight educational content for architectural curricula. The key points are:

- The use of advanced computer daylight simulations tools supports educational activities and aids architectural design, only if the students have an opportunity and time to comprehend the obtained results and reflect upon them;
- The gap in daylight education may be bridged by a choice of elective or mandatory classes or online consultations

Available informative packages should cover daylight appraisal tools suitable for architectural and urban design purposes.

2. BACKGROUND

The design of the modern built environment, which is human needs-oriented, energy-efficient, sustainable, and resilient, requires from its creators, to obtain the interdisciplinary skills and specialist knowledge, also in a field of daylighting technology. Therefore, architecture schools' curricula are regularly updated.

In Poland, 34 educational institutions (state or private) offer undergraduate and graduate architectural courses. Among five top universities (institutions with the highest ranking according to the Polish Accreditation Committee: PKA), with 7111 architecture students registered (2016), only one offers 60 hours of mandatory advanced lighting class. Thus, looking at the education curricula of those various schools, daylight analysis is not a part of mandatory architecture education. Some architectural departments offer non-mandatory courses on lighting and daylighting. In addition, sunlight evaluation and insolation training is offered as a part of non-mandatory continuing professional development (CPD) by different architecture- related associations.

The subjective and objective daylight appraisal within the built environment is not a mandatory part of architectural training in Poland.

There are numerous research examining correlations between subjective assessment and daylight metrics focusing on office and classroom environments [8]. The studies investigate students' performance [9], perception [10], perceived brightness [11] or emotional evaluation of daylight [12] using variety of methods. Some of the research includes the comparison of the participants' assessment and the results of the obtained daylight indicators including Daylight Autonomy [13, 14, 15, 16], DA, DGP and illuminance [17].

This article examines the relationship between students' subjective assessment of daylight in classrooms and the objective evaluation of daylight conditions using daylight simulations tools in the context of architectural and daylight education in Poland.

3. METHODS

The methodology applied followed the sequence of steps. The first step was a direct questionnaire given to 194 architectures students (BSc and MSc level) from there different universities located in three cities in Poland during 13 sessions under various sky conditions. The participates were asked to assess daylight within a given space, and answer quantitative and qualitative questions about their daylighting preferences and knowledge. The second step was computational daylight simulations conducted for each of 13 sessions. The third step involved a comparison of the results obtained using two methods followed by a formulating the general conclusions on methods and tools used.

3.1 Questionnaire construction

The primary objectives of the study were: to learn about correlations between daylight appraisal and students' knowledge on daylight parametrisation and normalisation. To study their daylight preferences and abilities to depict the luminous characteristics of the daylit interiors. The questionnaire consisted of the following parts:

- Statistical information the analysed space
- Drawing of a room with marked responder's position
- Questions focusing on daylighting characteristics
- Questions about daylight metrics
- Questions on daylight recommendations
- Preferences inquires

- Statistical information including responders' daylight educational background and design experience.

The secondary objective of the questionnaire was to highlight possible gaps in Polish daylight education for future architects and to formulate recommendations for use of daylight appraisal tools.

The students who took the (paper, tablet or smartphone) questionnaire were asked to appraise the daylighting conditions, temperature, window view, uniformity of task illumination within the enclosed space. Simultaneously the experts performed illuminance measurements and evaluated the daylight conditions within a room. The questionnaire sessions started in 2014 and continued with modifications until 2017. All recorded sessions took place at different times of the day (Table 1) and a year and under the various luminous conditions. The sky conditions in location Gdansk (54°22'N 18°38'E) and Sopot (54°26'N 18°33'E) were reported as mainly overcast. The sky conditions for location Poznan (52°25'N 16°55'E) was described a clear sky with the sun.

Table 1: General information about the sessions.

Nr	Location	Orienta-tion	Date / Time	Number of participants
1	Gdansk	SW	28.03.14/ 15	25
2	Sopot	E	31.01.15/ 12	24
3	Sopot	E	23.04.16/ 12	15
4	Gdansk	SE	27.11.16/ 12	16
5	Gdansk	NE	05.12.16/ 15	16
6	Gdansk	SE	05.12.16/ 14	17
7	Sopot	N	21.01.16/ 12	12
8	Sopot	N	08.04.17/ 12	13
9	Sopot	E	08.04.17/ 15	7
10	Poznan	W	01.06.17/ 13	12
11	Poznan	W	01.06.17/ 14	13
12	Poznan	W	01.06.17/ 15	13
13	Sopot	S	21.10.17/ 12	5

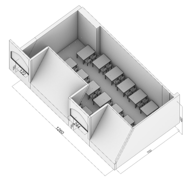
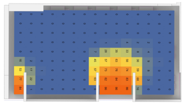
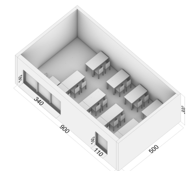
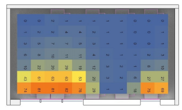
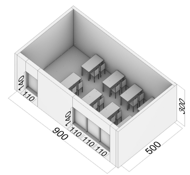
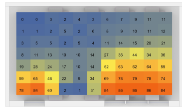
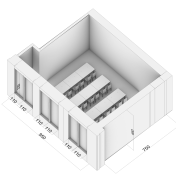
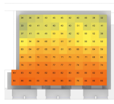
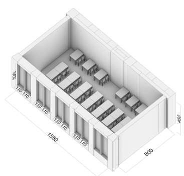
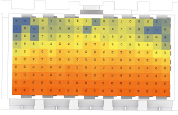
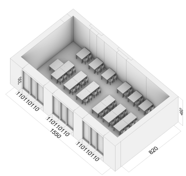
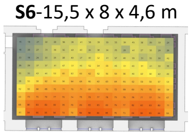
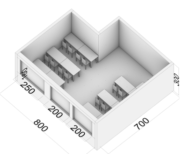
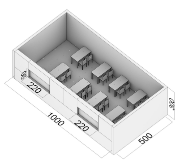
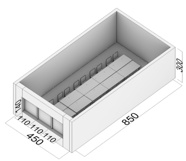
The participants were architecture students between 20 and 60 years old. The majority of the participants, 80% were between 20-30 years old. 15% of the participants were between their 30 or 40. The age groups 40-50 and 50-60 were the least represented (respectively 4 and 2 responders). The 69% of participants were women and 31% were men other gender groups were not reported.

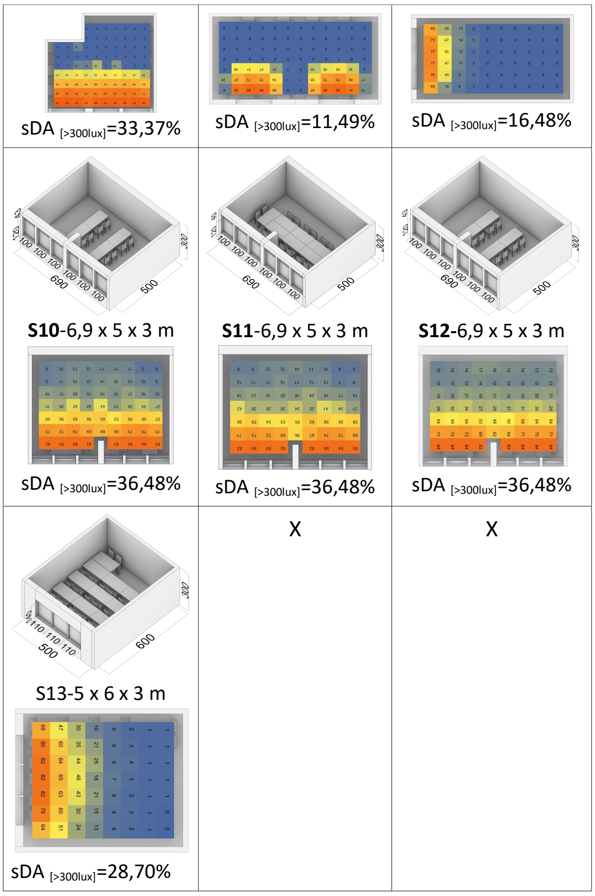
3.2. Computational evaluation procedure

The students' daylight appraisal results were compared with the daylight simulations conducted for all the classrooms. Three questions reflecting on a perception of daylight were selected form the questionnaire: (i) *How sufficient is lighting in the room?* (ii) *How would you describe daylighting?* (iii) *What is the uniformity of task illumination?* The answers to the question (i) were given in five-point scale ranging from: (I) *'very sufficient' – 'sufficient' – 'medium' – 'not sufficient' to 'not sufficient at all'*. The possible answers for questions (ii) and (iii) were: *'very good' – 'good' – 'medium' – 'poor' – 'very poor'*. The recorded responses were compared with daylight simulations of Daylight Factor (D) and illuminance levels.

The simulations were conducted using Rhinoceros 3D software [18] and DIVA plug-in [19]. All the 13 classrooms were modelled in Rhinoceros 3D software. The geometry and parameters (length, width, height) of the spaces and the size of window openings are shown in Table 2. Along with Daylight Autonomy results, the metric aimed at assessing the dynamic qualities of daylit spaces. sDA is represented as a percentage of annual daytime hours that a given point in space is above a specified illumination level [20]. The target level of illuminance required in the room has been set as 300 lx. The chosen classrooms were spaces where all the participants have weekly classes in and were familiar with seasonal dynamics of daylight within those spaces. However, during the appraisal, the students were asked to assess the observed daylighting.

Table 2: Models of the classrooms with dimensions in meters (length x width x height). Values of Spatial Daylight Autonomy $_{[>300lux]}$

 **S1**-12,6 x 7 x 4,6 m  sDA $_{[>300lux]}$=12,39%	 **S2**-9 x 5 x 3 m  sDA $_{[>300lux]}$=15,69%	 **S3**-9 x 5 x 3 m  sDA $_{[>300lux]}$=28,31%
 **S4**-9,5 x 7,5 x 4,6 m  sDA $_{[>300lux]}$=62,41%	 **S5**-15,5 x 8 x 4,6 m  sDA $_{[>300lux]}$=68,28%	 **S6**-15,5 x 8 x 4,6 m  sDA $_{[>300lux]}$=55,34%
 **S7**-8 x 7 x 3 m	 **S8**-10 x 5 x 3 m	 **S9**-4,5 x 8,5 x 3 m



Classroom furniture layouts were modelled according to the real layouts observed in the rooms. The optical properties of the materials were set as typical values for classroom, available by default in plug-in DIVA: GenericInteriorWall_50, GenericCeiling_70, GenericFloor_20, OutsideGround_20, OutsideFacade_35, Glazing_DoublePanel_Clear_80, GenericFurniture_50. The measurement points were arranged on the reference plane with spacing of 1,50m x 0,9m at height of 1,2m. The height of the measurements points relates to the average height of the eyesight of a sitting participant. There were no weather data files (.epw) available for location in Sopot. The university is located near a border between Sopot and Gdansk (within Tre-city system), therefore the weather data files for Gdansk were used.

4. RESULTS

The highest overall values of sDA (about 60%) were obtained in the selected rooms in Gdansk (sessions 4-6) with an exception for session 1 (an attic classroom with small window openings). The sDA values around 40% were received for classrooms assessed in Poznan (sessions 10-12). Significantly lower values of sDA were acquired for sessions 2, 3, 7, 8, 9 and 13, for Sopot.

The obtained results of the participants' perception of the daylighting and the simulations of the daylight conditions were presented in charts (Fig. 1-3). The mean students' appraisals for each session have been complied with the mean values of the chosen daylight metrics: DF and illuminance.

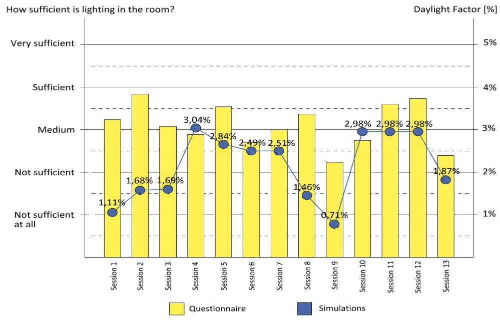


Figure 1: Results for question (i): How sufficient is lighting in the room? and Daylight Factor simulations. The chart shows: yellow bars – the mean values of the answers given to the question (i); in blue points – the mean values of the Daylight Factor in % calculated for each of the classrooms.

The responses to (i) *'How sufficient is lighting in the room?'* has been compared with the mean values of the Daylight Factor (Fig. 1). Daylight Factor is understood as a ratio of the illuminance at a point on a given plane due to the light received directly and indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, where the contribution of direct sunlight to both illuminances is excluded [20]. Daylight factor was chosen as a most common daylight metric [21] used in many daylight standards including the newest EN 17-037 [22]. All participants' responses were between the 'sufficient' and 'not sufficient' ranges. The overall daylighting conditions in all the rooms were evaluated on average as 'medium'. The classrooms with the most sufficient lighting, according to the responders, were rooms analysed in session 2, 11, 12. Sessions 11 and 12 were carried under clear sky but without direct sunlight (no glare recorded) in rooms with west orientation with a high view (according to 17-037 ratings) in the afternoon. These factors combined resulted in the high subjective evaluations of daylight sufficiency. These factors combined resulted in the high subjective evaluations of daylight sufficiency. The insufficient perceived lighting levels were reported in classrooms in session 9 and 13.

This results of subjective daylight appraisals correspond well with the simulation results. The biggest differences in values levels obtained by two methods were noticed in sessions 1-3 and session 8. The authors suspect that these fluctuations may be related to the spatial complexity of the classroom (session 1) or a large number of different window openings (sessions 2, 3, 8).

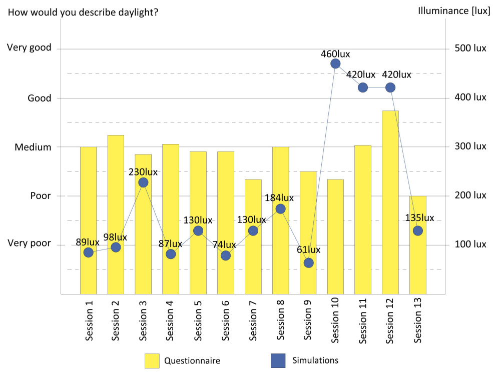


Figure 2: Results for question (ii) How would you describe daylight? and illuminance values: in yellow bars – the mean answers are given to the question (ii); in blue points – the values of illuminances simulated for a point in session time.

The responses to (ii) 'How would you describe daylight (in this space)?' have been collated with the mean illuminances values simulated per each classroom for each of the 13 sessions (Fig. 2). The illuminance at a point of a surface is understood as a quotient of the luminous flux dΦv incident on an element of the surface containing the point, by the area dA of that element [20].

The majority of the responders evaluated the daylight as 'medium' in almost all investigated classrooms. Only the single aspect classroom evaluated in sessions 13 obtained the lower 'poor' rating. The furniture arrangement in this space resulted in a situation where the participants facing the blackboard could not see the view out and the glazing openings located behind them.

The highest overall values of illuminances were in the range from 460 to 420 lx were obtained for sessions 10, 11 and 12 carried out in Poznan in rooms with 40% of sDA values.

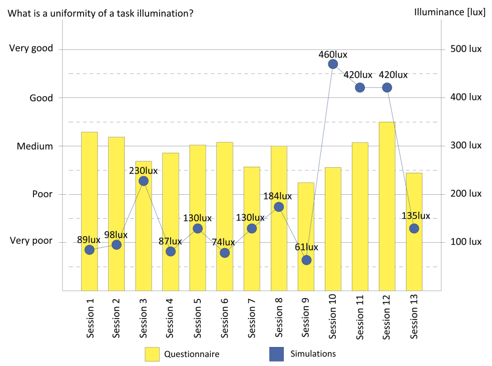


Figure 3: Results for question (iii) What is the uniformity of task illumination? and illuminance simulated: in yellow bars – the answers given to the question (ii); in blue points – the mean values of illuminance.

The question (iii) '*What is the uniformity of task illumination?*' results were confronted with the mean illuminance levels simulated for each of the classrooms for days and times of the sessions, taking into account available information about the sky type (Fig. 3). The uniformity of task illumination was rated as "medium" by the responders for all analysed spaces. The classes with the best-perceived uniformity levels (majority answers close to 'good' rating) were collected in sessions 3 and 9. Both rooms have East exposition.

There were significant differences in subjective perception results and simulated values for sessions 10-12, for classrooms located in Poznan. The highest illuminances were not associated with the best uniformly appraisals.

5. DISCUSSION AND CONCLUSIONS

The subjective participants' assessment of the observed daylight characteristics results differs from the objective results of Daylight Factor and illuminances at the point. The key findings are:

- (i) Daylight factor simulations results correspond with subjective students' assessments of daylight sufficiency within the rooms for eight out of 13 cases.
- (ii) The were no significant correlations found between the mean illuminances values and the subjective students' appraisals of daylight. The subjective description of daylight within the investigated classrooms was similar (medium) for all the sessions.
- (iii) The subjective perception of uniformity for task illumination was rated by observers as a medium, while the mean illuminance levels varied from 61 to 460 lx.

The results demonstrate that the individual daylight description results do not correspond with simulated illuminances. Thus, D values may from 2,8% to 3% indicate medium to sufficient assessment of daylight within the enclosed spaces.

The choice of the used metrics (D, the illuminance at the point on a surface), was dictated by their popularity in daylight analysis.

The study also revealed that geometry of the classroom, size of the window openings and their orientation are the key elements influencing the perception of the daylight conditions in the rooms. The subjective appraisal results illustrate that within the similar room geometry and location, the answers may vary significantly.

The choice of the of used metrics: D and the illuminance at the point on a surface was dictated by their presence in the recommendations and different design tools also used by architecture students like Revit, Daylight Visualizer.

The most decisions affecting daylight quality and quantity, and cost, energy optimisation, building mass layout, view in the outside, heat gain, users' satisfaction are made during the conceptual stages of urban and architecture design. The demand for accurate metrics to evaluate how fluctuating daylight performs, and the need to incorporate this information into the preliminary stage of the building design are crucial for designers. The comprehension of various daylight design alternatives and their implications for the environment and future residents equips designer with the necessary data which may significantly influence the final design decisions [2,13]. Furthermore, the information about direct sunlight performance, in an existing building, during the final development stages of the design may also implicate changes in a choice of shading system, glazing or interior finishes. Consequently, a necessity for a precise description of daylit environments has increased recently due to a need for creating low-energy buildings where human comfort performance is respected. The subjective daylight appraisal task followed by a simulation of daylight indicators was created to help architecture students to comprehend the daylight metrics. The disparities between subjective appraisal results and objective calculations may illustrate the imperfection of the used metrics.

The results of the questionnaire focusing on responders' skills to evaluate daylight within a room helped to formulate the first recommendation for daylight education for future architects. The key points are:

- Use of the contemporary daylight appraisal tools may be taught in a context of the spaces familiar to students or used by them (a user’s experience).
- The use of advanced computer daylight simulations tools can support educational activities. It also aids architectural design, but only if the students could comprehend the generated results and relate to them.

The limitation of the study includes a choice of questions and daylight metrics used. The disparities between subjective and objective assessments may be impacted by a limited number of spaces chosen for this study and the changing spectral characteristics of daylight.

The paper only present part of the research, and further work is planned concerning recorded view out, temperature, ventilation factors.

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