First Outcomes of an Investigation about Daylighting Knowledge and Education in Europe

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***Abstract*—DAYKE (Daylighting Knowledge in Europe) is a project to investigate the daylighting knowledge and skills of Architecture students and practitioners from different countries within the European Union. This paper introduces the first stage of the research and provides results from a direct survey taken by 161 students from seven schools of Architecture: two in Italy, one in The Netherlands, two in Poland and two in Spain. The results indicate significant national differences in preference and perception of daylit spaces. They also show a lack of knowledge about daylighting metrics and regulations among the respondents. Although the research is undergoing, the preliminary data analysis indicates that there is a need for enhancing the daylight knowledge among future architects.**

***Index Terms*-- Daylighting education, Daylighting knowledge, Daylit spaces assessment, EU regulation, Surveys.**

INTRODUCTION

The European Union (EU) invests many resources in the dissemination of new energy saving strategies and policies [1], [2] and electric lighting design issues have been addressed in several architectural studies and framework programs. Until now, this does not seem to be the case for daylighting design, metrics and recommendations. But this is changing. The daylight evaluation method specified in the *EN 15193* [3] is a step in that direction. Moreover, the daylight assessment methods suggested in the draft of the new European *Daylight of Buildings* Standard [4], [5] will greatly influence the design of the building environment. Architects of today and tomorrow will have great responsibility in delivering the generations of energy efficient buildings to come. It is therefore important that they understand daylighting regulations and their implications on the design.

However, recent studies have revealed that there is a general inadequate knowledge about lighting retrofitting and energy performance evaluation of modern lighting systems [6], [7]. Other studies show that the use of the latest daylighting evaluation tools and metrics remains limited, with practitioners tending to rely on simplified methods and rules of thumb in the early design stages [8], [9]. At the same time, it has been highlighted that there is a need for a better daylighting education [10].

The DAYKE (DAYlighting Knowledge in Europe) research project aims at understanding the status of daylighting education and practice in the EU. The research is focused on investigating: (a) the level of preparation among architecture students and practitioners; (b) the relationship between national daylighting regulations and possible cultural/geographic differences. The project is currently being carried out in Germany, Italy, The Netherlands, Poland and Spain.

PROJECT DESCRIPTION

DAYKE structure

DAYKE is a project based on a system of questionnaires (paper and online-based, all ad hoc developed by the Authors) designed to give complementary information about daylighting perception, education and knowledge.

The first questionnaire is paper-based (Questionnaire A) and is used to evaluate the Architecture students' ability to observe and describe the daylight conditions within a given space as well as their knowledge about daylighting metrics/indicators and regulations. The suggested protocol includes a description of the confined space (a classroom), a photographic documentation and a series of illuminance measurements over the workplanes are taken in the room during the questionnaire.

The second questionnaire is an online survey (Questionnaire B) for the investigation of the differences between conceived and actual daylighting knowledge (on daylighting metrics, regulations, design tools and assessment techniques) and on the national existing daylighting design practice.

The third questionnaire is also an online survey (Questionnaire C) that focuses on the educational offer regarding lighting and daylighting design topics and on the practice of lighting and daylighting design in the Architecture profession in the different countries. The questionnaire is addressed to university staff of several faculties of Architecture for each participating country as well as to professionals.

The project is divided into three stages, corresponding to the three questionnaires.

- Stage 1, currently undergoing and based on Questionnaire A, aims at linking the daylighting topic to the education of European university students combining perceptual, cultural and general knowledge aspects.
- Stage 2 (Questionnaire B) aims at widening the investigation to designers (and other students) for a better understanding of the existing practical knowledge about daylighting.
- Stage 3 (Questionnaire C) is aimed at understanding the relationship between the previously obtained data and the daylighting educational offer in Europe.
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Stage 1 - Questionnaire A (QA)

6) *Work plan*

The specific objectives of the first stage are: (a) to assess students' ability to describe the daylight conditions within a given space in comparison to the assessments done by two experts (university professors or DAYKE staff) and to measured illuminance levels; (b) to learn about students' preferences towards daylighting; (c) to assess students' general knowledge about daylighting; (d) to find which aspects of daylighting knowledge are missing in the architectural curricula.

the investigation on the perception (see next Section) was based on a benchmarking method that compares the judgments expressed by expert and non-expert respondents , consistent with already done in other studies about perceived environmental quality [11]–[13]. This first stage started in Winter 2017 and will be completed in Autumn 2017. It consists of collecting and evaluating 250 questionnaires taken by undergraduate and graduate students from universities in each country involved.

7) *Questionnaire A content*

Questionnaire A (QA) contains questions about: *Perception* (overall environment, luminous environment); *Preferences* (daylighting preferences) and *Knowledge* (daylighting knowledge). Questions had either an open-ended or a rating nature. For the rating questions, a 5-point rating scale was used. Data on the socio-demographic and daylighting education information of the participants is also collected.

STAGE 1 – FIRST OUTCOMES

This paper presents the results obtained from eight sessions of the first stage that took place between January and May 2017, involving 176 responses from the following faculties:

- Faculty of Architecture, Sapienza University of Rome and Faculty of Architecture, Roma Tre University, in Italy.
- Faculty of Architecture and the Built Environment, TU Delft, in The Netherlands.
- Faculty of Architecture, Poznan University of Technology and the Faculty of Architecture, Sopot University of Applied Science, in Poland.
- Barcelona School of Architecture (ETSAB) and Vallès School of Architecture (ETSAV), Universitat Politècnica de Catalunya, BarcelonaTech (UPC), in Spain.

The survey was completed by 40 students and 2 experts in each session.

Data analysis

The data analysis was performed using Excel and SPSS software v24. Descriptive statistics were plotted for each variable of interest. To check for any significant differences between the experts and undergraduate and graduate students a series of Chi square tests were performed for the categorical variables. For the ordinal variables, each variable considered in the study underwent Kolmogorov-Smirnov tests to control for any possible deviations from a normal distribution. As the test showed that many variables could not be considered normally distributed, the data was analysed by means of a series of non-parametric Mann-Whitney U tests. The following is a summary of the most representative results that were obtained.

8) *Perception: Comparison between experts' and students' reports*

The analysis showed that the ratings provided by the students and those given by the experts were overall quite similar. The only exceptions were found in:

- Spain, regarding the daylight quantity, with the students' evaluation of daylight being significantly poorer compared to the experts ($U=14.00$, $p<.01$);
- The Netherlands, regarding the daylight quantity, with students rating daylight significantly better than the experts ($U=12.50$, $p<.05$) and the possibility to control it, with students being significantly less satisfied compared to the experts ($U=12.50$, $p<.05$)

9) *Preferences: The best and the worst daylighting design example choices and reasons*

The students gave more "best" than "worst" examples of daylighting design. Approximately 2/3 (64.7%) gave a "best" example of daylighting design but not all of them could explain the reason for their choice (57.1%). "Worst" daylighting design examples were given by 59.0% of the students, while the reason for their choices was explained by 55.3% of them only. The Italian students were the least able to express their "best" daylighting design examples (60.0%) and in providing arguments to support them (22.5%). On the contrary, 88.1% of the Spanish students were able to provide "best" and "worst" daylighting design examples and the reasons for their choices.

a) Types of choice

Notably, a significant difference between the types of positive and negative examples given was observed, as one could expect (Fig.1a). As "best" examples, students focused on the function of the building (e.g. museums, libraries, greenhouses etc.) hereby called *general*, as well as on the significant features of exceptional architectural buildings, hereby called *exemplar.* Examples of the *exemplar* category include buildings like the Kimbell Art Museum or the Solomon R. Guggenheim Museum. For the "worst" daylighting designs, students have mostly provided examples drawn from their first-hand experience in their university buildings, houses or dormitories, hereby called *subjective*.

b) Reasons for choice

The responses regarding the reasons for the choices (open answers) were divided into eight categories: *Architectural quality, Quantity of light, Daylighting design strategy, Energy saving, Devices, Functional reason, Environmental and visual comfort reason,* and *Other* (Fig.1b).

The students reported *Daylighting strategy* (28.3%), *Quantity of daylighting* (25%) and *Architectural quality* (19.6%), as the first reasons behind their "best example" choices. The arguments provided vary by country:

- Spanish (50%) and Polish (33.3%) students reported more interest in the amount of incoming daylight.
- Italian (20%) and the Dutch (50%) students reported more interest in the daylighting design strategy.

The first arguments provided for the "worst" daylighting design example choices were: *Environmental and visual comfort* (29.2%), *Quantity of daylighting* (27%) and *Functional reasons* (14.6%).

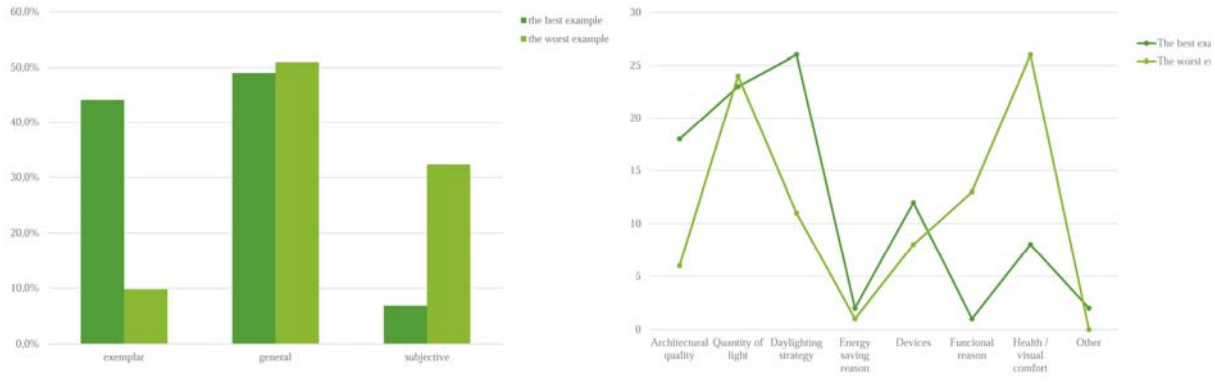

Figure 1. Preferences for the best and the worst daylighting design example: 1.a - (Left) Percentage of responses, grouped by type. 1.b - (Right) Reasons justifying the choices, by type.

10) *Preferences: greatest barrier to daylighting design*

This question was intentionally ambiguous to reveal the students' approaches to daylighting. The responses demonstrate a tendency to focus on a quantitative dimension and a propagation of daylight t (34.2%). Students also pointed out the difficulty in managing daylight due its seasonal and climatic variability (28.9%) and the risk of excessive solar gain/greenhouse effect (20.2%) as barriers to daylighting. It should be noted that only the Dutch students considered the financial cost (direct or indirect) as a barrier to daylighting design.

11) *Preferences: Expectations from daylighting design*

With regard to the expectations from daylighting, the Chi square tests showed that:

- Polish and Dutch students particularly expected the daylight to provide a view to the outside ($\chi^2(3)=27.74$, $p<.01$).
- Italian students expected daylight to replace electric light and to be energy efficient ($p<.05$ in both cases)
- Spanish, Dutch and Polish students expected daylight to provide a cosy and pleasant atmosphere ($\chi^2(3)=11.49$, $p<.01$)

In relation to daylighting regulations, the analysis pointed out that Polish students would welcome regulations significantly more than the students from other countries ($\chi^2(3)=12.66$, $p<.01$). It is worth noting that currently there isn't any standard or guidance on daylighting in Poland.

12) *Knowledge: Daylighting metrics/indicators*

Table I shows the results for the daylighting metrics knowledge questions. It can be seen that 43.5% of students claimed to know a daylighting metric or indicator. Interestingly, the analysis showed that only very few among them was able to correctly name them (65.2% gave 'false positive' answers). The number of 'true positive' answers revealed that 14.9% only of the students did actually know a daylighting metric. The Chi square did not show any significant relationship between country and the self-reported knowledge.

TABLE I. KNOWLEDGE ABOUT DAYLIGHITNG METRICS/INDICATORS AND INCIDENCE OF FALSE POSITIVES

Question	**Answers**	**Country responses**									
		Italy		***The Netherlands***		***Poland***		***Spain***		***Total***	
Knowledge about metrics/ indicators[a]	YES	20	50.0%	18	42.9%	18	52.9%	14	31.1%	70	43.5%
	NO	20	50.0%	21	50.0%	16	47.1%	31	68.9%	88	**54.7%**
	No answer	0	0.0%	3	7.1%	0	0.0%	0	0.0%	3	1.9%
Name of the metrics/ indicators[b]	true positive	6	28.6%	10	55.6%	2	11.1%	6	50.0%	24	34.8%
	false positive	15	71.4%	8	44.4%	16	88.9%	6	50.0%	45	**65.2%**

a. Do you know any daylighting metrics/ indicators?
b. If yes, what daylighting metrics/indicators do you know?

13) *Knowledge: Regulations concerning daylighting design*

Table II shows the positive responses concerning the knowledge of regulations. It can be seen that 3.7% only of the students declared to know a EU regulation concerning daylighting (but no one was able to name it). Only 19.9% declared to know the national regulation concerning daylighting design or an energy efficiency regulation. It seems that Polish and Dutch students are more informed concerning regulations, although the numbers are still too low to generate clear data.

TABLE II. KNOWLEDGE ABOUT REGULATIONS (POSITIVE RESPONSES)

Questions	**Country positive responses**									
	Italy		***The Netherlands***		***Poland***		***Spain***		***Total***	
Daylighting EU regulation[a]	2	5.0%	2	4.8%	2	5.9%	0	0.0%	6	**3.7%**
Daylighting national regulation[b]	5	12.5%	6	14.3%	9	26.5%	12	26.7%	32	**19.9%**
Energy-saving regulation[c]	7	17.5%	10	23.8%	7	20.6%	8	17.8%	32	**19.9%**

a. Do you know any EU regulation concerning daylighting design?
b. Do you know any National regulation concerning daylighting design?
c. Could you please give an example of any regulation (building, energy-efficiency) regarding daylighting, solar gain or shading?

Preliminary results

With reference to students' perception of the lighting conditions in the classrooms tested, the results show that a similar interpretation of the luminous environment is shared between the students and the experts.

It can be inferred from the results that there are divergences among students from different countries concerning daylighting preferences and expectations The following trends have been identified on this:

- The Dutch students denote a greater attention to light control (*perception*), visual comfort (the *worst example*), variability *(the greatest barrier*) which could be related to their preference for the design strategies (*the best example*). Those aspects are in line with their expectations for pleasantness and view to the outside (*expectations*).
- The Italian students pay more attention to architectural quality and daylighting design strategies (the *best example*) and the quantity of light for the negative aspects (the *worst example* and the *greatest barrier*). The latest may illustrate their expectations for the energy savings (*expectations*).
- The Polish students take notice of the quantity of light (the *best example*) and functional reasons (the *worst example*).
- The Spanish students show a greater interest on the quantity of light than on the qualitative aspects of daylight (*perception*; the *best example* and the *worst example;* the *greatest barrier*).

Distinct daylighting preferences between the faculties of southern of Europe (Italy and Spain) and of northern Europe (The Netherlands and Poland) were not found.

Regarding the daylighting knowledge, the results show deficiencies among all students, regardless the country. The high percentage of the 'false positive' answers to the daylighting metrics question can be interpreted in two different ways: either the students do not know the terminology or they did not understand the question. Either way, the results suggest that students are unfamiliar with the technical aspects of daylighting.

With respect to daylighting standards, all students were unable to name a European standard concerning daylighting. If a lack of knowledge regarding European regulations could be expected, the lack of knowledge about national regulations remains surprising. Less than one out of five respondents indicated to know a national legislation concerning daylighting or energy efficiency. The situation is slightly better in Poland and in the Netherlands, but the numbers are still very low.

CONCLUSIONS

As a summary, the first outcomes of the DAYKE project show that there are three major tendencies:

- The perception of quality of daylit spaces for students and experts is similar;
- Regarding cultural aspects (daylighting design know-how, preferences and expectation), students from different countries pay a different degree of attention to diverse aspects of daylighting design. There were no significant differences of interpretation found between South (Italy and Spain) and North of Europe (the Netherlands and Poland). A significant influence of the educational programmes on the responses of the students from the UPC Barcelona and from TU Delft was also noticed. In Italy and Poland, the students involved in the survey do not have any compulsory daylighting courses and the tendency is to consider daylighting from a non-technical viewpoint.
- Despite different educational offers, all the students have a low level of knowledge about daylighting metrics and standards. These findings confirm observations from previous studies and highlight the importance of considering its introduction in architectural curricula.

The complete results from the first stage of the DAYKE project will hopefully provide a better understanding of the differences regarding the daylighting education offer to the future architects of different European countries. It is expected this to help in formulating recommendations for a successful education in this field, in Europe.

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