FILLING THE GAPS: SHAPING LIGHTING EDUCATION FOR THE FUTURE

LIGHTING METROPOLIS WP6.1

Bech-Larsen, Pernille; Linnebjerg, Sofie; Mullins, Michael Finbarr

Publication date:
2017

Document Version
Accepted author manuscript, peer reviewed version

LIGHTING METROPOLIS WP6.1
SECTION 1

FILLING THE GAPS:
SHAPING LIGHTING EDUCATION FOR THE FUTURE

PERNILLE BECH-LARSEN
SOFIE LINNEBJERG
MICHAEL MULLINS

FILLING THE GAPS:
SHAPING LIGHTING EDUCATION FOR THE FUTURE
SECTION 1

Skriftserie: Arkitektur & Design (A&D Files) Aalborg Universitet
ISSN nr. 1603-6204
Volumen nr. 113

Forfattere:
PERNILLE BECH-LARSEN
SOFIE LINNEBJERG
MICHAEL MULLINS

September 2017, København

FOREWORD

This report forms part of the Lighting Metropolis research project. As one of the work packages under this project, the report investigates the current educational programmes in lighting related fields in Denmark and Sweden and relates these programmes to the employment needs for lighting competencies. Thus, its intention is to map the 'gaps' between current supply and demand of lighting related skills in the private, public and educational sectors, and to recommend areas in which these gaps can be reduced.

This research has been carried out by Aalborg University in collaboration with a group of Lighting Metropolis partners during the period from October 2016 to September 2017. The work package established a task force which met a number of times during the course of the study and which offered valuable advice and guidance to the researchers. The task force group compromised the following members:

Task force group:

- *Michael Mullins: Work package leader, AAU*
- *Sif Enevold: Lighting Metropolis project leader, Gate 21*
- *Anders Nilsson: Lighting Metropolis project coordinator, Innovation Skåne*
- *Johan Moritz: Senior lighting designer, City of Malmø*
- *Jakob Sidenius: Chief Consultant, Growth & Regional Development - Albertslund Municipality*
- *Søren Nørgaard: IoT and Smart City Strategist – TDC*

The research and report has been primarily been carried out by Pernille Bech-Larsen and Sofie Linnebjerg under the project leadership of Michael Mullins. We have further been assisted at various times by Anton Flyvholm, Kathrine Marie Schledermann, Andreas Wulff-Jensen and Lektor Hendrik Purwins.

TABLE OF CONTENTS

INTRODUCTION: LIGHTING METROPOLIS

Vision and Mission of Lighting Metropolis

The Lighting Metropolis (LM) project is the first decisive step in realizing a vision for Greater Copenhagen as the world's leading Living Lab for lighting application. Covering Region Skåne in Sweden, the Capital Region of Copenhagen, and Zealand in Denmark, Greater Copenhagen is home to 3.8 million inhabitants.

The primary aim is to strengthen the significant role lighting can play in supporting safety, accessibility, identity, health, and education for people in cities. A second Lighting Metropolis target is to facilitate and support the Greater Copenhagen region tapping into the significant growth potential of these areas as they expand globally and exponentially. As part of this vision, the project seeks to engage private companies, municipalities, organizations and institutions of knowledge to provide the project with the best possibilities for success. The project is funded by Interreg Öresund-Kattegat-Skagerrak.

Lighting Metropolis will put Greater Copenhagen as a central player in the rapidly expanding area of smart urban lighting, where regions, municipalities, private businesses, and knowledge institutions collaborate to develop a destination for visitors looking to see the latest and best solutions in lighting and related smart city technology taken off the drawing board and into the streets.

This goal will be reached by 1:1 scale projects and experiments that can help generate new knowledge and opportunities when lighting up the urban city. New collaborations between companies and research departments can add value to future investments in the Region.

Work Package: WP6.1

Light has been shown to have a significant impact on our daily lives, in fields as health, learning, work and general wellbeing. [1] Training and knowledge of lighting is therefore becoming a more widely sought professional quality in Denmark and Sweden. Accordingly, in 2012 the Danish Centre for Light undertook a limited investigation of existing lighting related educations at university level in Denmark. The report concluded that there was a need for specialised, cross-disciplinary educations in Lighting Design at a Master's level. [2] Recent research suggest that the building industry, including architects and consulting engineers, will be responsible for 40% of green growth, with more than 11.000 fulltime jobs by 2035 and 19,5 bill. DKK. [3] This opens up a huge potential in jobs with lighting related competencies within energy and building alone.

A recently released report from the Danish ministry of research and education "FORSK2025" indicates research possibilities within technology and green growth souch as smart city, iOT urban environment and Big data. [4]

As part of LM, the aim of WP 6.1 has been to map and analyse the present supply and demand of competencies within lighting related fields. That is to say, the study has looked at current educational programmes within a broad field of lighting and compared this 'supply' to the current 'demand' by employers in the region. The research adds to the overall LM goals by identifying and contributing to the establishment and growth of particularly those competencies which are currently weak or lacking in the Region. This approach attempts thus to lay the foundation for a comprehensive strategy for how to reduce the 'gap' between labour demand and the provision of education services in the lighting field.

Mapping out the available competencies can also strengthen and expand lighting related educations in the Region, by opening up new possibilities for collaborations between municipalities, industry and educational institutions. Establishing future scenarios within this context can lead the way for beneficial new partnerships to improve international competitiveness. Building a strong relation between educations and employers in the Region can prove to be beneficial for all parties, including municipalities, private companies as well as the educational institutions themselves.

The field of lighting is undergoing rapid development and is expanding to include an increasing number of disciplines - from technical and humanistic to artistic practices, on practical as well as theoretical levels. The goal of WP6.1 has therefore been to create an overview, which enables the development of a comprehensive strategy that reflects the labour market demand, together with the composition and organization of the supply-side of education. The purpose is thus to ensure relevant and well-trained lighting professionals from the educational programs, that supply the interdisciplinary lighting industry in Greater Copenhagen.

METHOD

Surveys

Initially, to define the primary themes for this project, a broad range of competencies were identified within the field of lighting. To validate these competencies and categories, a focus group with selected participants was presented with an initial definition, and after discussion and debate, the competencies and categories were developed. Together with a comparison of previous findings from LYSNET.dk and the "key topics" identified in the DCL report [2], the final distribution describes 111 competencies and 8 categories (see appendix A).

An extensive screening of educational programmes in Denmark and Sweden was then carried out to identify which programmes potentially offer relevant lighting related courses. The educational institutions include universities, university colleges, architectural schools, engineering colleges, stage and art schools, Swedish Högskolar, professional bachelors and electricians. Relevant search-words were identified and a comprehensive online search was composed for each of the competencies.

Based on findings from UddannelsesGuiden (www.ug.dk), studere.nu and studentum.se, almost 300 educations were found to be potentially relevant to the 111 competencies and of these 150 educations were, after a fine-meshed screening, adjudged relevant to take part in a survey.

Online surveys were created using SurveyXact, containing all 111 competencies divided into the 8 topics. The questions employed a Likert scale to determine to what degree the included educations "supply" the 111 competencies. Before finalizing the questionnaire an online pilot test was carried out in a group of 15 selected participants to identify errors.

In January 2017, 152 respondents from different educations were contacted by phone before the survey was sent out, in order to encourage and motivate participation. The selection of this group was based on the spread in the different professional groups; the different kinds of educations; and to what extent it was estimated that the education provides lighting-related competencies. The 'supply' survey was finished and distributed by the beginning of February. All respondents were sent two reminders and 84 useable responses were received.

Subsequently an almost identical online survey was created, directed to the 'demand' for the 111 competencies by companies and municipalities. Relevant contact-persons were located via industry related websites and Danish and Swedish light associations, such as: Innovationsnetværk Dansk Lys (DK), Elforsk (DK), Lysnet.dk (DK), Sydljus (SE), Ljuskultur (SE), Belysningsbrachen (SE) and Lighting Metropolis (DK + SE). Additional advertisement for the survey was included in the newsletters for members of DCL (Dansk Center for Lys, DK) and Sydljus (SE). Personal email-accounts were gathered online and all demand-participants received the survey as an email, with introduction to the project via SurveyXact. A few random people received a phone call or a personal email. This resulted in 435 contact persons and 92 usable answers.

Analysis

Data from the 'supply' survey were subjected to a descriptive analysis, once the desired amount of 80 respondents was reached. Subsequently the data from the 'demand' surveys were also analysed by descriptive analysis. The results from the two initial survey analyses were then compared and major gaps between supply and demand were initially identified.

Subsequently Wilcoxon Signed-Rank statistical tests were carried out on the survey results, where 'supply' answers were paired with 'demand' answers. This non-parametric test is suitable for paired samples and is based on the ranks of the absolute difference in the values of each pair of Likert scale responses. The findings of the initial descriptive analysis were generally supported by the statistical methods.

To validate the results of the statistically significant gaps and the future possibilities of research, education and collaboration, we then interviewed 17 prominent European personalities in lighting. Interviews were partially transcribed, highlighting only relevant parts of the interviews. The quantitative results of the current situation in Denmark and Sweden combined with the qualitative findings from the expert interviews resulted in hypotheses for the current situation, the immediate future and in a 5-10 year perspective.

In June 2017, 14 representatives from industry, municipalities and educations were gathered at Aalborg University in Copenhagen to take part in two focus groups. The results from the surveys, findings and preliminary hypotheses based on the series of expert interviews, were presented to these two focus groups, which consisted of representatives from Denmark and Sweden.

A final analysis was carried out thereafter to review new information and implement the focus group's perspectives in the findings, and to rank and recommend the competencies in need of higher educational support in the future.

RESULTS

Supply

160 respondents were contacted, 51% completed the survey, 5% partially completed the survey, 4% were discarded and 40% didn't answer. This resulted in 84 useful answers from various Scandinavian educational institutions of all kinds above high school, including 52% master studies, 18% bachelor studies, 6% professional bachelor studies, 17% professions and 7% others.

For the completed and partially completed, the country and gender distribution resulted in 63% Danish, 37% Swedish. 22% were female and 78% were male. (Figure 1)

Demand

435 respondents were contacted, 18% completed the survey, 6% partially completed the survey, 3% were discarded and 72% didn't answer. This resulted in 92 useful answers from industry, including 10% architects, 4% building consultants, 11% consulting engineers, 5% daylight advisers, 7% from the energy sector, 21% lighting designers, 14% manufacturers, 11% municipalities, 1% sales and 16% others.

For the completed and partially completed, the country and gender distribution resulted in 63% Danish, 37% Swedish. 25% were female and 75% were male. (Figure 1)

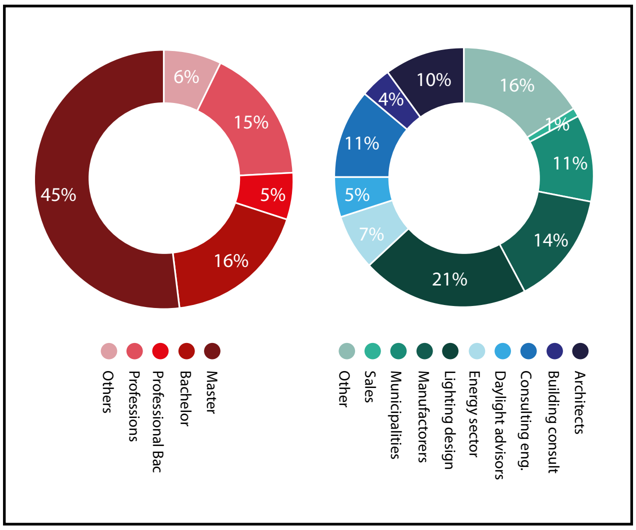

Figure 1: Answers based on educational level and sector.

Crossing borders

To give an overview of the distribution of supply and demand, survey participants have been plotted with red and blue respectively to flag, on map of Denmark and southern Sweden (see figure 2). Due to the size difference, five educations in the northern part of Sweden, including two educations in Luleå, two in Umeå 2 and one in Sundsvall are not included in figure 2. The illustration shows that the concentration of lighting related competencies is currently highest in the larger cities, and particularly in Greater Copenhagen.

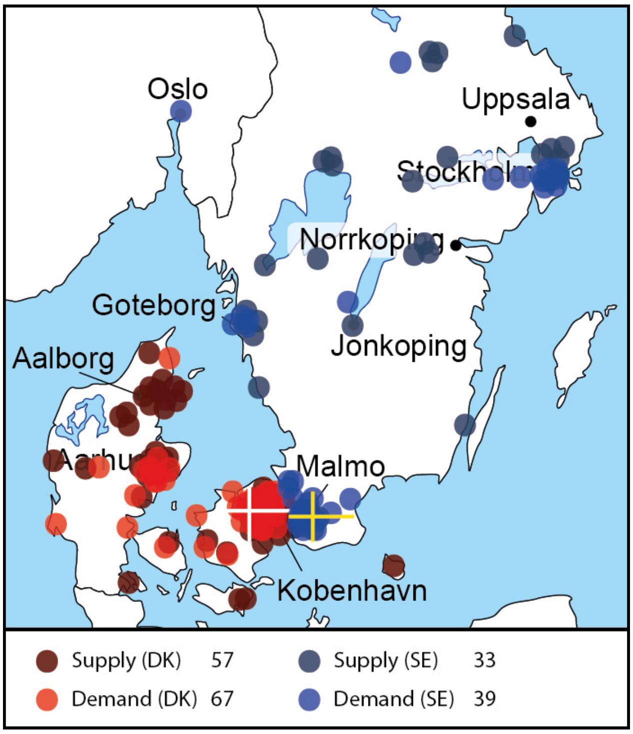

Figure 2: Geographic distribution of survey participants, divided in supply and demand. Red dots representing Danish answers and blue dots representing Swedish answers

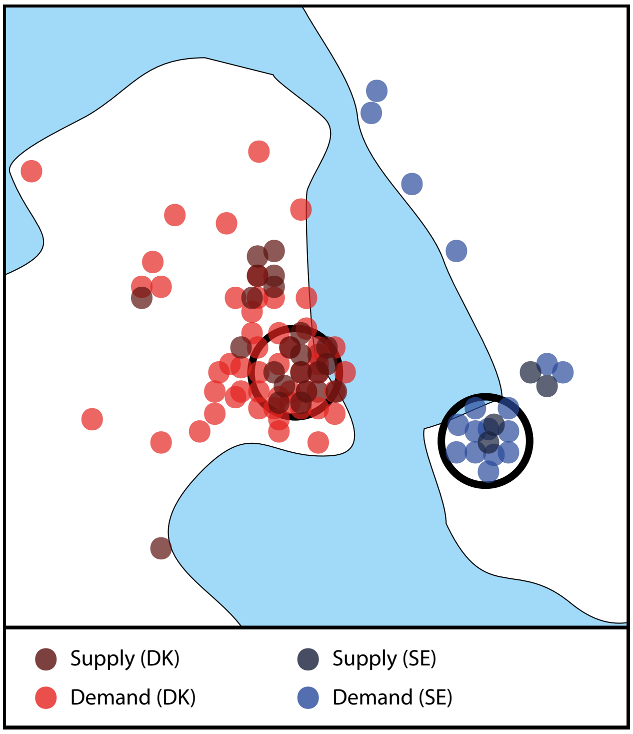

Figure 3: Distribution of survey participants in the Greater Copenhagen area

Gaps – statistics

For the two online surveys, results are derived from the survey data and based on a Likert scale of 1-4, where 1 = not at all, 2 = to lesser degree, 3 = to some degree and 4 = to high degree. The additional option was provided to choose "don't know" and add a comment. Answers of "don't know" have been discarded. All 111 categories from the survey were investigated and the biggest gaps were identified and categorised through a descriptive analysis.

To investigate these findings more thoroughly, we applied statistical analysis in the form of a Wilcoxon Signed-Rank test. Statistical significance supported indications of the effect of the gaps, thereby allowing a more reliable end result and final categorisation of the identified gaps between supply and demand.

Table explanation (Table 1)

All results have been collected in Table 1 by combining all the information to provide an overview of each of the competencies and categories.

The first column of the table states the category of priority. Selected competencies were categorised with pink (high priority), orange (some priority), yellow (less priority) and white (no priority).

The second column indicates the characteristic of the gap: 'd' the gap is big because the demand is very high (average >3), 's' when the supply is very low (average <2) and "d/s" when a competence has both a high demand and a low supply.

The third and fourth columns show a colour code based on the average S (supply) and D (demand). Bright red (lowest <1,5) – yellow (average 2,25-2,5) – highest (dark blue >3,45) (see Table 1, 2 of 2 for entire scale)

The fifth column indicates how big the gap between the averages of supply and demand is. Green = good <0,75, white = okay 0,76-0,90, blue = not good 0,91-1,24, pink = alarming > 1,25.

The next three columns show the findings from the statistical Wilcoxon ranked sum analysis. More red dots (1-3) equal bigger statistical evidence of the gap. (1) If Effect Size > 0.3 and either mean or mode have a measureable difference >2. (2) If last test is true = if effect size >0,3 and supported by two measures = difference in both mean and mode >2. (3) If last test = true,

Categ	Dom	Sup	Dem	GAP	Statistics			Number + name		Supply - Level			Av	Sup	Dem	Demand - sector				Av
1	2	3	4	5	6	7	8	**01.00**	**Light & Experience**	11	12	13	14	15	16	17	18	19		20
								01.01	Light culture and traditions	D	E	B				7	10	11		
								01.02	Art - with the use of light	E	B	D				7	9	11		
	d							01.03	Architectural lighting	E	D	A				5	4	8	3	1
	s/d							01.04	Landscape Planning and light	C	A	D				7	8	9		
								01.05	Communication - with the use of light	B	D	E				4	1	7		
								01.06	Visual perception	E	A	C				4	5	2		
	d							01.07	Atmosphere - including the use of lighting	E	D	B				4	7	9		
								01.08	Materials and its lighting properties	D	E	A				4	1	2		
	d							01.09	Aesthetics - in relation to the light / lighting / lamps	E	D	B				4	7	5		
	s							01.10	Sensory experiences - including the use of lighting	E	C	A				11	2	9		
								01.11	Shadow and form drawing	E	B	A				4	7	9	1	
										E	**D**	**A**	**E**			**4**	**7**	**9**		**7**
								02.00	**Light, Health & Wellbeing**											
	s							02.01	Biological lighting	E	A	B				4	1	11		
								02.02	Light and circadian rhythm	E	A	B				4	11	9		
	s							02.03	Human centric lighting	E	A	B				4	1	9		
								02.04	Effects of visible light on humans	E	A	B				4	9	1		
								02.05	Effects of non-visible light on humans	E	A	B				4	9	8		
								02.06	Optometry	C	A	E				11	9	4		
								02.07	Light in medical technology	A	E	B				5	4	9		
								02.08	Visual ergonomics	E	C	A				2	8	6		
								02.09	The eye's anatomy and physiology	E	C	A				4	11	9		
	d							02.10	Working environment and lighting	E	D	A				4	7	9	2	6
										E	**A**	**B**	**A**			**4**	**9**	**9**		**4**
								03.00	**Light & Technology**											
								03.01	Sensor technology	D	A	E				10	2	9		
								03.02	Optics and lenses	E	B	A				4	2	10		
								03.03	Light source development	D	E	B				4	2	10		
								03.04	Light source manufacturing	E	D	A				10	4	9		
	d/s							03.05	Luminaire design	E	D	A				2	4	5		
	s							03.06	Luminaire manufacturing	E	A	D				2	10	6		
	s							03.07	Wireless lighting	D	A	B				2	6	4		
	d/s							03.08	Interface for lighting control	D	E	A				5	10	2		
										D	**A**	**A**	**D**			**2**	**2**	**9**		**2**
								04.00	**Light & Energy**											
								04.01	Energy consumption	D	C	A				10	4	2	9	6
								04.02	Solar energy	A	D	C				5	4	9		
								04.03	Power system design	D	A	C				9	5	3		
								04.04	Power Systems and Building Construction	D	C	A				9	5	3		
								04.05	Building Integrated energy production	C	D	A				5	4	9		
								04.06	Introduction to energy classes	D	C	A				9	3	4	5	
	d							04.07	Energy friendly light sources	D	E	C				4	5	9	10	6
	d/s							04.08	Energy renovation (including lighting)	D	A	C				5	9	4	2	3
										D	**C**	**A**	**D**			**5**	**4**	**9**		**9**
								05.00	**Light & Planning**											
	d/s							05.01	Light strategies	E	A	B				4	9	3	7	5
	s							05.02	Lighting masterplans	E	A	D				4	3	7	5	
	d/s							05.03	Light planning	E	B	A				9	4	8	2	3
	d/s							05.04	Economy	D	C	E				4	9	10	3	
	d							05.05	Lighting legislation	D	E	A				5	4	10	9	3
	d/s							05.06	Urban design and lighting	E	A	B				4	9	7	3	5
	d							05.07	Technical descriptions (including lighting)	D	E	C				5	9	4	3	
	d/s							05.08	Tender specifications (including lighting)	E	D	C				9	5	3	4	10
								05.09	Light signals	C	A	D				6	9	10		
	s							05.10	Traffic lighting	A	D	E				6	2	9		
	d/s							05.11	Public lighting	E	D	A				2	9	8		
	s							05.12	Light pollution	E	A	D				4	2	9	1	
	s							05.13	Safety lighting	D	E	C				9	8	11		
								05.14	Panic lighting / escape lighting / emergency lighting	D	C	A				9	5	3		
								05.15	Working environment and lighting	E	D	A				4	9	2	6	
	s							05.16	Landscape planning and light	E	A	D				4	9	7	3	5
	d/s							05.17	Lighting concept development	E	B	A				4	8	1	3	7
								05.18	Luminous signs	E	D	B				10	9	1	8	
								05.19	Communication using lighting	B	A	D				4	5	1	9	
	d/s							05.20	Project planning (including lighting)	B	E	C				4	7	9	3	5
	d/s							05.21	Lighting standards	D	E	A				4	5	9	2	
								05.22	Building Act - in relation to indoor electric lighting	D	A	E				4	9	7	8	
	s							05.23	Building Act - in relation to outdoor electric lighting	D	E	A				4	8	3	7	
	s							05.24	Road lighting	E	A	D				6	4	10	9	

Table 1: Comprehensive overview of analysis results (1 of 2)

Categ	Dom	Sup	Dem	GAP	Statistics			Number + name		Supply - Level			Av	Sup	Dem	Demand - sector				Av
	s							05.25	Commissioning and maintenance (of lighting)	D	E	A				9	2	10		
								05.26	Commissioning and maintenance (of computerised sy	D	B	A				9	11	10	5	
										E	A	A	E			4	9	10		9
								06.00	**Daylight**											
								06.01	Daylight openings	E	D	A				4	7	1	3	5
								06.02	Building construction	E	A	C				3	4	1	7	
								06.03	Daylight and spatial design	E	A	D				1	7	9	4	
	s							06.04	Facades	E	A	B				7	1	8		
								06.05	Glass, glass coatings etc.	E	A	C				4	1	7		
								06.06	Daylight and thermal comfort	A	E	D				4	5	7	3	
								06.07	Daylight autonomy	E	A	D				1	4	11		
	s							06.08	Shading systems	E	A	D				4	1	7		
								06.09	Building components of glass (other transparent mate	E	A	C				4	1	7		
								06.10	Surrounding environments influence on daylighting	E	A	D				7	1	4		
								06.11	Windows and rooflight	E	A	D				4	1	7		
	s							06.12	Daylight sensors	D	E	C				4	7	3	10	
								06.13	Daylight factor	E	D	A				4	7	9	1	
	s							06.14	Daylight calculation	E	A	D				4	9	1		
	s							06.15	Useful Daylight Illuminance (UDI)	A	E	B				4	9	5		
								06.16	Surface design (surface, reflectance, texture etc.)	E	A	B				7	1	4	10	3
										E	A	C	E			4	1	7	3	4
								07.00	**Digitalised Light**											
	d							07.01	Light simulation	E	B	A				4	2	3	7	9
	d/s							07.02	Intelligent lighting	D	E	A				10	2	11	7	
	s							07.03	Interactive lighting	D	E	A				10	2	1	4	11
								07.04	Computer rendering	B	E	A				4	1	3		
								07.05	Virtual reality	E	A	B				4	1	7		
	s							07.06	Programming	D	B	E				4	10	5	3	7
								07.07	Virtual models	B	E	A				4	7	3	1	
								07.08	Software development	B	A	B				11	10	4		
	s							07.09	Applications	D	E	B				4	11	10	7	
	s							07.10	Smart City	E	A	B				6	2	10	4	
								07.11	Big Data	E	B	A				4	10	1	11	
										E	E	B	E			4	2	3	7	4
								08.00	**Light Characteristics & Measurements**											
								08.01	Radiation	E	C	A				4	11	9	5	
	d							08.02	Glare	E	D	A				2	10	9	11	4
								08.03	Colour rendering	E	D	A				4	5	10	9	
	d							08.04	Colour temperature	E	D	B				10	4	5	2	
	d							08.05	Flicker	E	D	A				4	11	8	5	
	d							08.06	Evaluation of light sources	E	D	A				9	10	3	4	5
								08.07	Calibration of measuring equipment	C	E	A				10	3	8		
								08.08	The use of light measuring instruments	E	A	D				4	1	8	9	
								08.09	Light measuring methods	E	A	D				4	3	10	9	
								08.10	Biometric data collection	E	C	A				4	11	1	10	
	d/s							08.11	Evaluation of luminaires	E	D	A				2	9	4	5	
								08.12	Spectral distribution	E	A	B				4	2	11	5	
								08.13	Diffusion of light	E	B	A				4	2	10	1	
								08.14	Transmission of light	E	A	C				4	1	2		
								08.15	Reflection of light	E	B	A				4	1	2	10	
								08.16	Refraction of light	E	C	A				4	2	9	8	
								08.17	Photonics	E	A	B				4	5	1		
								08.18	Photometry	E	A	B				4	2	8		
	d							08.19	Light calculation	D	E	A				2	3	9	4	5
	s							08.20	Light sources - aging and degradation	E	D	C				2	10	4	8	
	d/s							08.21	Calculation Software (Radiance, DIALux, OptisWorks,	E	D	A				2	9	3	8	
										E	D	A	E			4	2	9	5	4

Av Gap size
<0,75
0,76-0,90
0,91-1,24
>1,25

Highest
DK
SE
DK some
SE some

Importance level
HIGH
SOME
LES

#	Sector
1	Architects
2	Luminaire manu
3	Building owner consult
4	Daylight advisers
5	Sales
6	Municipality
7	Landscape arch
8	Lighting Design
9	Consulting Engineers
10	Energy sector
11	Other

#	Level
A	Master
B	Bachelor
C	Professional Ba
D	Profession
E	Other

Dominant
d = high demand
s = low supply
d/s = high + low

Average
<1,5
< 2
<2,25
2,25-2,5
>2,5
>3
>3,25
>3,45

Table 1: Comprehensive overview of analysis results (2 of 2)

supported by the two measures and effect size > 0.5.

Ninth and tenth columns state the name and number of the topics and competencies.

Columns eleven to thirteen rank the three educational levels with the highest supply in that category and column fourteen the most frequent number in that topic. The same applies to columns seventeen to twenty; here the numbers indicate the sector that has the highest demand. If numbers are red, the supply/demand is very low all over. If green, the demand is very high all over the categories and maybe in more than three.

The last two columns, fifteen and sixteen, refer to the above mentioned educational scores, but are related to nationality where red represents Denmark and blue represents Sweden. A darker colour shows that the supply/demand is convincingly higher in either DK or SE, while if the colour is light, the supply/demand is higher, but not to the same degree.

DISCUSSION

Pros and cons

Mapping the gaps between the educational supply on the one hand, and demand from the interdisciplinary lighting industry on the other, in both Denmark and Sweden has proved to be a very complex undertaking. A number of decisions have therefore been taken to both define and limit the study. These include a definition of the employers (municipalities and industries) as being located within the Greater Copenhagen Region, while educational programmes have been taken to include the entire area of Denmark and Sweden. This decision was made early in the study, on the basis that employers do not necessarily rely on local educations to provide the knowledge they require. However, it may be argued that the development of education pointed out by the study might be placed in the Region with advantages to both education and employers. This discussion has not however been developed further in this study and remains to be dealt with as part of an overall Lighting Metropolis strategy.

Furthermore, the selection of the Likert Scale for collecting quantitative data has proved to have both benefits and disadvantages. One of the benefits was the option to combine all 111 competencies into one questionnaire suitable for the many kinds of participants. This open approach allowed, in an almost identical questionnaire, the combination of various educational levels, institutions, courses, and systems into one group of respondents, while allowing the combining of a wide variety and size of "demanders" from the private and public sector, including municipalities, artists, international engineering companies, architect firms, salesmen and lighting designers, into the second group of respondents.

The survey could in this way embrace all these different kinds of respondents and use this to accommodate the variety to be found in the context of the study. Reaching a minimum of 80 participants from both groups was set as the target. While this was in fact achieved, in the supply-survey the response rate was 51%, which despite personal phone calls and email-correspondence was lower than the goal of 70% of the invited participants. This may have been influenced by the inclusion of a long introduction text and 111 questions, some of which had little or no relevance for some participants. Additional bias may have occurred through relevant educations not having participated, while others provided an overlap of many of the same competencies.

The measure of the survey questions is on the Likert scale, namely the terms "high degree" "some degree" "lesser degree" and "not at all". To some degree, respondents have thus answered based on their subjective understanding of these levels, leading to the possibility of bias in results; for example one educator may have valued the inclusion in their curriculum of a 15 ECTS course with the answer of "4 - supply to a high degree", while another may have estimated a 5 ECTS course with a similar value. The survey has however intentionally not taken the measure of ECTS merits as indicative of the degree of supply (as the Danish Centre for Light has previously attempted) [2]. This is primarily due to the fact that questions and answers based on ECTS may be similarly misleading, as many aspects of lighting education are to be found within courses dealing with other subjects: one example of this is light and energy, which often falls within the broader courses on sustainability. This would force respondents to make subjective estimates of the portion lighting constitutes of the total course. It has therefore been preferred to attempt to elicit respondents' views on the total picture offered within their areas.

Randomisation

To keep the order of themes and sub-points, all participants answered the questions in the same order. In a longer survey such as this one, where we attempted an average answer time of 8 minutes, participants may become impatient, annoyed or merely bored toward the end of the survey. If so, this can cause bias in the answers to the last themes compared to the first themes. In the partially completed answers, we see that especially the 'demand' participants tended to quit the survey in the middle of theme 5, Light and planning. This can also indicate that participants in online-surveys lose concentration after approximately 50 questions.

Tendencies

When comparing the results and analysis from both surveys, the demand was higher than the supply in all 111 questions. This might suggest a tendency that the educational suppliers were more careful when stating to what degree they educate in the different fields, and that people on the demand side exaggerate what they need and want from the people they employ. It may however also be interpreted that there is simply a higher demand than there is supply in all 111 categories. However to accommodate this apparent imbalance, the gap in supply and demand is only considered significant when the difference between the average values is above 1,25 on the scale from 1-4. (See Table 1, row 5)

Another tendency suggests that the biggest suppliers of lighting-related education are among university colleges (*"professions højskoler"*), although an exception to this is *#4 light & energy*, where engineering programmes supply at a high level. The highest demand varies more over the 8 themes. (See Table 1, row 11-13)

Looking at the geographical distribution of supply based on themes, there is a tendency towards a higher Danish supply in all themes with the exception of *#2 health & wellbeing*, where the Swedish supply is higher and *#8 Characteristics and measurements* where the distribution is more level. Demand based on country is much more inconsistent, with a strong tendency towards higher Swedish demand in *#1 experience*, *#2 health & wellbeing* and *#8 Characteristics and measurements* and a higher Danish demand in *#4 light and energy* and *#6 Daylight* as well as a small tendency in *#7 Digitalized light*. (See Table 1, row 15-16)

Investigating the popularity of the competencies compared to the 8 themes, we have a strong tendency towards a high demand in *#4 Energy* and *#5 Planning* and *#8 Characteristics and measurements*. This can imply that filling gaps within these are more interesting for the industry right now. (See Table 1, row 17-20)

Consequences

The gaps have been divided into three categories based on the dominant factor responsible for the gap, i.e.: significantly low supply, higher than average demand or a combination of high demand and low supply (See Table 1, row 2). Additionally, all 111 categories have been evaluated on gap size, statistical significance of gap and popularity. The most significant gaps were divided into three final categories, to determine the priority of these (See Table 1, row 3-8).

CONCLUSIONS

This study supports the findings of previous studies, in particular the DCL-report from 2012 [1], which indicated a high demand for interdisciplinary qualifications in Denmark, that the lighting industry was lacking specialised skills related to lighting design and that many were willing to offer internships and collaborative projects. Research from The Danish technological institute in competencies, jobfunctions and demand within the engineering field suggest that in 2020 the engineers able to work in a cross-discilipnairy field will be in high demand [5] and earlier research, anticipating future skills and jobfunctions in the labour force, from the European union in 2010 [6]

The present study qualifies and expands this previous research while providing a finer mesh of detail concerning the needs for future educational programmes.

Statistical analysis of the surveys highlights the significant gaps between supply and demand. These areas and competencies have been identified and categorised. The biggest gaps have been located and systemised into three categories ('high', 'some', and 'less' priority) to provide a guideline for future action (See table 2). In Table 1, row 1, the priority is also highlighted with pink for the highest priority, orange for some priority and yellow for lesser priority.

Primary priority

Areas with the largest gaps between supply of education and employment demand include the following, categorised as highest priority.

In the pink category, marked as high priority in table 2, we find 18 competencies from six different topics. Of these 18, 11 have a large gap based on a combination of low supply (average<2) and high demand (average>3) whereas 7 don't have a significantly high demand, but a very low level of supply (average<2).

1.04 Landscape planning and light: Supply is low, average 1,7 and 57% answered "not at all" and demand is high with 94% of the answers stating that this is in demand and an average of 3,1.

2.03 Human Centric Lighting: There is interest from the lighting industry, but the supply is very low. 69% of the participants answered "not at all" while 85% have a demand of knowledge in this area and an average of 2,9.

3.05 Luminaire Design: A skill that can be found in design and architecture. Supply is low, 50% answered "not at all" while demand is high, with 89% of the answers stating that this is in demand and an average of 3,1.

4.08 Energy Renovation: For private and public buildings and for cities. Supply is low, 52% answered "not at all" while demand is high, with 93% of the answers stating that this is in demand and an average of 3,2.

5.02 Lighting Master Plans: Zooming out and taking a view from above. Supply is low, 74% answered "not at all" while demand is average, with 87% of the answers stating that this is in demand and an average of 2,8.

5.03 Light planning: In every project involving lighting design, the lighting has to be planned in collaboration with architects, landscape, engineers etc. Supply is low, 46% answered "not at all" while demand is very high, with 97% of the answers stating that this is in demand and an average of 3,4.

5.04 Economy: Very important in every business but not as interesting in a research point of view. Supply is low, 54% answered "not at all" while demand is high, with 95% of the answers stating that this is in demand and an average of 3,2.

5.06 Urban design and lighting: Lighting and landscape can be important for the image and growth of an area and a good opportunity to collaborate. Supply is low, 62% answered "not at all" while demand is high, with 92% of the answers stating that this is in demand and an average of 3,1.

5.08 Tender specifications – including lighting: Being able to read and understand specifications and project requirements is not an important part of the agenda at most schools. Supply is low, 46% answered "not at all" while demand is very high, with 95% of the answers stating that this is in demand and an average of 3,3.

5.11 Public lighting: Supply is low, 53% answered "not at all" while demand is very high, with 92% of the answers stating that this is in demand and an average of 3,3.

5.17 Lighting concept development: Creativity and mastering new concepts. Supply is low, 64% answered "not at all" while demand is very high, with 97% of the answers stating that this is in demand and an average of 3,2.

5.20 Project planning and light: Project management and planning is a skill that many employees require after they finish school. Supply is low, 52% answered "not at all" while demand is very high, with 93% of the answers stating that this is in demand and an average of 3,0.

5.24 Road lighting: Keeping up with national standards for safety and illuminance, glare etc. Supply is very low, average 1,4 and 76% answered "not at all" and demand is average with 80% of the answers stating that this is in demand and an average of 2,8.

5.25 Commissioning and maintenance of lighting: Working in engineering companies and municipalities. Supply is very low, average 1,7 and 72% answered "not at all" and demand is average with 86% of the answers stating that this is in demand and an average of 2,9.

7.10 Smart City: Understanding IoT and what the collected data can be used for is a newly required skill. Supply is very low, average 1,4 and 68% answered "not at all" and demand is average with 79% of the answers stating that this is in demand and an average of 2,5.

8.11 Evaluation of Luminaires and light sources: Quality and post evaluation is in demand. Supply is low, 61% answered "not at all" while demand is very high, with 87% of the answers stating that this is in demand and an average of 3,1.

8.20 Light sources – aging and degradation: Supply is low and 60% answered "not at all" and demand is average with 89% of the answers stating that this is in demand and an average of 2,9.

8.21 Calculation Software: Using a range of calculation programmes, to test lighting concepts and show proof of specifications in a project. Supply is low, 66% answered "not at all" and demand is very high with 88% of the answers stating that this is in demand and an average of 3,2.

Secondary priority

In the orange category, marked "some priority" in table 2, we find 16 competencies from six different topics. Of these 16, 2 have a big gap based on a combination of low supply (average<2) and high demand (average>3), 6 have high demand (average>3) and 8 a low level of supply (average<2).

PRIORITISED RANKING OF COMPETENCIES IN NEED OF ATTENTION

PRIMARY	SECONDARY	TERTIARY
1.04 Landscape planning and light	2.01 Biological lighting	1.03 Architectural lighting
2.03 Human centric lighting	2.10 Working environment and lighting	1.07 Atmosphere - Incl. the use of lighting
3.05 Luminaire design	3.06 Luminaire manufacturing	1.09 Aesthetics in relation to light, lighting, lamps
4.08 Energy renovation (including lighting)	3.07 Wireless lighting	1.10 Sensory experiences - Incl. the use of lighting
5.02 Lighting masterplans	4.07 Energy friendly lighting	3.08 Interface for lighting control
5.03 Light planning	5.01 Light strategies	5.05 Lighting legislation
5.04 Economy	5.12 Light pollution	5.07 Technical descriptions (including lighting)
5.06 Urban design and lighting	5.23 Building Act - outdoor electric lighting	5.10 Traffic lighting
5.08 Tender specifications (including lighting)	6.12 Daylight sensors	5.13 Safety lighting
5.11 Public lighting	6.14 Daylight calculation	5.21 Lighting standards
5.17 Lighting concept development	7.02 Intelligent lighting	6.04 Facades
5.20 Project planning (including lighting)	7.03 Interactive lighting	6.08 Shading systems
5.24 Road lighting	8.02 Glare	6.15 UDI
5.25 Commissioning and maintenance (lighting)	8.05 Flicker	7.01 Light simulation
7.10 Smart City	8.06 Evaluation	7.06 Programming
8.11 Evaluation of luminaires	8.19 Light calculation	7.09 Applications
8.20 Light sources - aging and degradation		8.04 Colour temperature
8.21 Calculation Software (Radiance, DIALux, Optis Works, Relux, CalcuLuX etc.)		

Table 2: The biggest gaps categorised and prioritised in high, some and lesser priority

2.01 Biological lighting: Supply is very low, average 1,5 and 67% answered "not at all" and demand is high with 86% of the answers stating that this is in demand and an average of 2,7.

2.10 Working environment and lighting: Supply is low, average 2,4 and 29% answered "not at all" and demand is very high with 97% of the answers stating that this is in demand and an average of 3,4.

3.06 Luminaire manufacturing: Supply is very low, average 1,4 and 73% answered "not at all" and demand is high with 79% of the answers stating that this is in demand and an average of 2,5.

3.07 Wireless lighting: Supply is very low, average 1,5 and 62% answered "not at all" and demand is high with 90% of the answers stating that this is in demand and an average of 2,7.

4.07 Energy friendly lighting: Supply is low, average 2,3 and 33% answered "not at all" and demand is very high with 95% of the answers stating that this is in demand and an average of 3,3.

5.01 Light strategies: Supply is low, average 2 and 51% answered "not at all" and demand is high with 94% of the answers stating that this is in demand and an average of 3.

5.12 Light pollution: Supply is very low, average 1,8 and 54% answered "not at all" and demand is high with 94% of the answers stating that this is in demand and an average of 2,8.

5.23 Building Act - outdoor electric lighting: Supply is very low, average 1,5 and 71% answered "not at all" and demand is high with 86% of the answers stating that this is in demand and an average of 2,6.

6.12 Daylight sensors: Supply is very low, average 1,7 and 63% answered "not at all" and demand is high with 85% of the answers stating that this is in demand and an average of 2,8.

6.14 Daylight calculation: Supply is very low, average 1,8 and 61% answered "not at all" and demand is high with 79% of the answers stating that this is in demand and an average of 2,7.

7.02 Intelligent lighting: Supply is low, average 1,9 and 52% answered "not at all" and demand is high with 93% of the answers stating that this is in demand and an average of 3,1.

7.03 Interactive lighting: Supply is very low, average 1,8 and 59% answered "not at all" and demand is high with 89% of the answers stating that this is in demand and an average of 2,8.

8.02 Glare: Supply is low, average 2,3 and 41% answered "not at all" and demand is very high with 93% of the answers stating that this is in demand and an average of 3,2.

8.05 Flicker: Supply is low, average 2,3 and 46% answered "not at all" and demand is very high with 91% of the answers stating that this is in demand and an average of 3,1.

8.06 Evaluation: Supply is low, average 2,2 and 40% answered "not at all" and demand is very high with 92% of the answers stating that this is in demand and an average of 3,2.

8.19 Light calculation: Supply is low, average 2,2 and 47% answered "not at all" and demand is very high with 93% of the answers stating that this is in demand and an average of 3,2.

Tertiary priority

Areas needing less attention including the following are categorised as the ones with the lesser priority: In the yellow category, marked "lesser priority" in table 2, we find 17 competencies from six different topics. Of these 17, 2 have a big gap based on a combination of low supply (average<2) and high demand (average>3), 7 have high demand (average>3) and 8 a low level of supply (average<2).

1.03 Architectural lighting: Supply is low, average 2 and 46% answered "not at all" and demand is very high with 99% of the answers stating that this is in demand and an average of 3,3.

1.07 Atmosphere - Incl. the use of lighting: Supply is low, average 2,4 and 31% answered "not at all" and demand is very high with 98% of the answers stating that this is in demand and an average of 3,3.

1.09 Aesthetics in relation to light, lighting, lamps: Supply is low, average 2,3 and 39% answered "not at all" and demand is very high with 96% of the answers stating that this is in demand and an average of 3,3.

1.10 Sensory experiences - Incl. the use of

lighting: Supply is very low, average 2 and 45% answered "not at all" and demand is high with 98% of the answers stating that this is in demand and an average of 3.

3.08 Interface for lighting control: Supply is low, average 2 and 44% answered "not at all" and demand is high with 94% of the answers stating that this is in demand and an average of 3.

5.05 Lighting legislation: Supply is low, average 2 and 43% answered "not at all" and demand is very high with 97% of the answers stating that this is in demand and an average of 3,2.

5.07 Technical descriptions (including lighting): Supply is low, average 2,2 and 34% answered "not at all" and demand is very high with 96% of the answers stating that this is in demand and an average of 3,2.

5.10 Traffic lighting: Supply is very low, average 1,2 and 87% answered "not at all" and demand is high with 55% of the answers stating that this is in demand and an average of 2,1.

5.13 Safety lighting: Supply is very low, average 1,6 and 59% answered "not at all" and demand is high with 86% of the answers stating that this is in demand and an average of 2,6.

5.21 Lighting standards: Supply is low, average 2 and 47% answered "not at all" and demand is high with 93% of the answers stating that this is in demand and an average of 3,1.

6.04 Facades: Supply is very low, average 1,8 and 59% answered "not at all" and demand is high with 85% of the answers stating that this is in demand and an average of 2,7.

6.08 Shading systems: Supply is very low, average 1,8 and 60% answered "not at all" and demand is high with 72% of the answers stating that this is in demand and an average of 2,5.

6.15 UDI: Supply is very low, average 1,5 and 70% answered "not at all" and demand is high with 76% of the answers stating that this is in demand and an average of 2,5.

7.01 Light simulation: Supply is low, average 2,1 and 51% answered "not at all" and demand is very high with 89% of the answers stating that this is in demand and an average of 3.

7.06 Programming: Supply is very low, average 2 and 50% answered "not at all" and demand is high with 87% of the answers stating that this is in demand and an average of 2,8.

7.09 Applications: Supply is very low, average 1,8 and 58% answered "not at all" and demand is high with 82% of the answers stating that this is in demand and an average of 2,5.

8.04 Colour temperature: Supply is low, average 2,5 and 35% answered "not at all" and demand is very high with 92% of the answers stating that this is in demand and an average of 3,3.

TOP 10 GAPS

1. (8.11) Evaluation of luminaires
2. (5.17) Lighting concept development
3. (5.06) Urban design and lighting
4. (5.04) Economy
5. (5.11) Public lighting
6. (8.21) Calculation Software (Radiance, DIAL-ux, Optis Works, Relux, CalcuLuX etc.)
7. (5.24) Road lighting
8. (1.04) Landscape planning and light
9. (5.03) Light planning
10. (5.08) Tender specifications (incl. lighting)

Figure 1: The top 10 gaps based only on the size of average supply and demand from the survey.

Gap size

The three above mentioned categories: primary, secondary and tertiary take all quantitaive parameters into account and suggest which competencies to look into. Looking isolated at the size of the gap, depending on the average supply and demand from the survey gives us an overview of the biggest gaps, ranked from 1-10 where 1 has the biggest gap. (Figure 1) All competencies in the top 10 of gaps are considered with primary priority. (Tabel 2)

RECOMMENDATIONS

The study has indicated areas which require attention, if the Lighting Metropolis aims are to be realised in the future. The gaps between, on the one hand, the competencies required by employers and, on the other, the competencies provided through educational programmes should be addressed in terms of improving and expanding the curricula at all levels of the educational system.

Furthermore, derived from discussions and debates in the expert interviews (Appendix B) and focus groups (Appendix C) carried out under this study, we further recommend that future curricula also take the following points into consideration:

- *More interdisciplinary projects*
- *More projects with external partners*
- *Collaborations with public projects and internships at municipalities*
- *The lighting industry needs more knowledge of which competencies to demand, when hiring new employees.*
- *Students should be aware of their possibilities in the market. No one needs to be an expert on everything. Many respondents from the industry are in need of a little knowledge of everything, whereas huge companies need people that are specialised.*
- *Short courses for employee brush-up*
- *Student "master class" in reading and understanding required skills: standards, planning, legislation and other skills you that you don't get familiar with in universities*
- *Economy is also an important parameter when leaving the academic world*

The above priorities are important for educational programmes and institutions to note, toward generating research, knowledge and graduates who can meet the rapidly changing demands within the lighting industry and related fields.

REFERENCES

[1] SSL-erate Consortium 2014 (2014). SSL-erate · FP7-ICT-2013-11-619249 · Deliverable D3.2 and 3.4 · Lighting for health and well-being in education, work places, nursing homes, domestic applications, and smart cities. Situation analysis report on lighting for health and well-being. [online] SSL-erate. Available at: http://lightingforpeople.eu/2016/wp-content/uploads/2016/03/SSLerate-3.2-3.4-v4.pdf [Accessed 8 Aug. 2017].

[2] Dansk Center for Lys, Innovationsnetværket Dansk Lys (2012). Behov for lysuddannelse i Danmark. Dansk Center for Lys.

[3] Sustainia (2017). Grøn Vækst i Greater Copenhagen – et indblik i Danmarks grønne job- og vækstpotentiale. Energi på Tværs. [online] Gate 21. Available at: https://www.gate21.dk/netvaerk-videndeling/groen-vaekst-i-greater-copenhagen/ [Accessed 8 Aug. 2017].

[4] Styrelsen for Forskning og Uddannelse (2017). FORSK2025 – fremtidens løfterige forskningsområder. [online] Styrelsen for Forskning og Uddannelse. Available at: http://ufm.dk/publikationer/2017/forsk2025-fremtidens-lofterige-forskningsomrader [Accessed 8 Aug. 2017].

[5] Teknologisk Institut (2013). Den Danske ingeniør 2020 – Jobfunktioner og Kompetencekrav. [online] Teknologisk Institut. Available at: https://www.teknologisk.dk/kompetencekrav-til-ingenioeren-i-2020/34048 [Accessed 8 Aug. 2017].

[6] Danish Technological, Institute ÖSB Consulting, Warwick Institute for Employment Research (2010). Anticipating skill needs of the labour force and equipping people for new jobs: which role for public employment services in early identification of skill needs and labour-skilling?. [online] Brussels, Belgium: European Commission, 2010. Available at: http://www.skillsforemployment.org/KSP/en/Details/?dn=WCMSTEST4_038626 [Accessed 8 Aug. 2017].