Invited Paper

The Need for Lighting Education

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ABSTRACT

It is amazing that in a world now dominated by light — a world that is absolutely dependent upon light — that there is almost no lighting education. In a few countries of the world there exist tertiary level lighting programs but these can be counted on the fingers of two hands. Developments in lighting technology have produced a range of design tools that can lead to improved and energy-efficient lighting. However, most of this technology is "harder" to use than traditional technology, emphasising the need for not only improved lighting education but for its initiation. This paper discusses the need for education and uses the example of the University of Sydney program as a possible basis for others to use. It also examines how it is being delivered in Singapore.

1. INTRODUCTION

Lighting — actually, electric lighting — has existed for just over 120 years. Lighting dominates our world and it is inconceivable to image what life was like without abundant light. Life would be dominated by seasonal and diurnal availability of daylight. Most of our nighttime activities would be impossible. Our 24h lifestyle would also be impossible.

It is surprising that the provision of lighting is usually by untrained people — sometimes professional engineers — who have little if anything of the human needs regarding lighting or the technical needs of lighting equipment. In this paper, the term "lighting designer" will be used to include those who call themselves "illuminating engineers", etc.

2. COMPLEX NEEDS

Lighting, like engineering and architecture, is an urgent practical endeavour. It is urgent in that lighting solutions are needed immediately rather than when there is a complete knowledge of all matters. It is practical for the same reason. Problems are often poorly described and where models of behaviour or performance exist, they are often weak.

Lighting design does not take place in a vacuum. As well as the other designers, there are matters concerning environmental protection, limiting unwanted effects on others, energy efficiency, statutory requirements, urban design objectives, technical performance and compliance with Standards and best practice. The designer needs to be able to interpret ideas from clients and others in the design team. The designer also needs to be able to tell people, from many different backgrounds, his/her ideas using a language and media that is understandable by each. Lighting design is not just selecting luminaires and lamps but concerns the creation of solutions to design problems.

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3. LIGHTING IS FOR PEOPLE

Much of the hard knowledge of lighting has come from physics, since it was involved in developing metrology, some calculation methods and, with chemisty, the creation of lamps. Engineers have dominated the applications arena of lighing. With rare exceptions, engineers and physicists tend to look at lighting as a physical problem and ignore the human element. And when they do not, they are frustrated by the wide range of human behaviours and preferences.

This is somewhat surprising, since photometry is based on a human response. Radiometric quantities are converted to photometric by the application of the relative luminous efficiency function ($V(\lambda)$, for photopic vision) and K_m, the maximum luminous erfficacy (= 683 lmW^{-1} at 555nm). While there is "acceptance" of the need for $V(\lambda)$, other aspects of lighting seem to be treated as mechanistic, in blind ignorance of the reality of seeming. There is not the space to explore these issues further but the point is that a well educated lighting designer needs to know about people, as well as, since and technology.

4. COMPLEX TECHNOLOGY

Lamps are very complex pieces of technology, whose purpose is to convert electrical energy into visible radiation, as efficiently as possible and to produce nominally white light. The last point is essential — white light is needed to reveal a coloured world. Metamerism suggests that the white needs to contain sufficient wavelengths in order that colours remain "true" under various illuminants. Lighting designers need to understand who lamps produce light and they must understand humabn colour vision in order to appreciate the limitations of lamps.

The lighting manufacturing industry has provided many new products; especially new lamps. These are more energy efficient than those of the past and many have longer lives and improved colour properties and colour stability. However, in most cases the new lamps are much more critically dependent upon correct electrical and thermal conditions to achieve their promised performance. They are less tolerant to bad luminaire design.

Similarly, dimming systems need to be competently designed in order that the systems both work and do not compromise lamp performance.

And of course, the greatest forgotten factor in lighting design is maintenance. It is totally unrealistic to select high quality luminaires, with energy efficient control gear if the lighting system is not maintained after installation. There is an ongoing need to clean luminaires, especially in polluted environments, if performance is to be achieved.

5. AN EXAMPLE — EXTERIOR LIGHTING

5.1 Building floodlighting

This needs to be done in a coherent manner. Lighting from below renders façades differently from daylight, since modelling is produced by upward rather than predominantly downward shadows. Further, stray light tends to go straight into the sky, resulting in increased sky glow which, while it might be an "amenity" in lighting the city, is pollution which reduces the enjoyment of the night sky by placing a veil of light over stars. It also greatly impedes optical astronomy.

Floodlighting from above, produces similar modelling to that from daylight and reduces sky glow. However, to avoid the unsightly appears of outriggers in daylight there is the added cost of retractable outriggers.

5.2 Pedestrian dominated areas

There is increasing interest in lighting pedestrian dominated areas of cities and towns to both increase the amenity of those areas and to reduce the perceived and possibly real fear of crime. Here it is vital to ensure adequate vertical illuminances on people's faces (for identification of features/intent) but in doing so to minimise discomfort and disability problems due to luminaire and lamp luminances. In general, if these objectives are to be achieved using post-top luminaires, large spaces require a forest of poles and pedestrian walkways require closely spaced luminaires. Sometimes, reflected light from façades can be used to achieve reasonable vertical illuminances, as well as increasing the surround (background luminances).

5.3 Standards assist designers

Some countries have extensive standards to assist lighting designers in producing environmentally responsible, high quality outdoor lighting. Australia is a good example with regard to the lighting of pedestrian dominated outdoor areas/roads[1] and in the control of the unwanted effects of spill light. The latter is also the basis of the work of CIE Technical Committee 5.12 which is finalising its recommendations[2] (CIE, 2001). Where national standards do not exist, the recommendations, where they exist, of CIE Technical Reports or CIE Standards might be used or those standards of other countries.

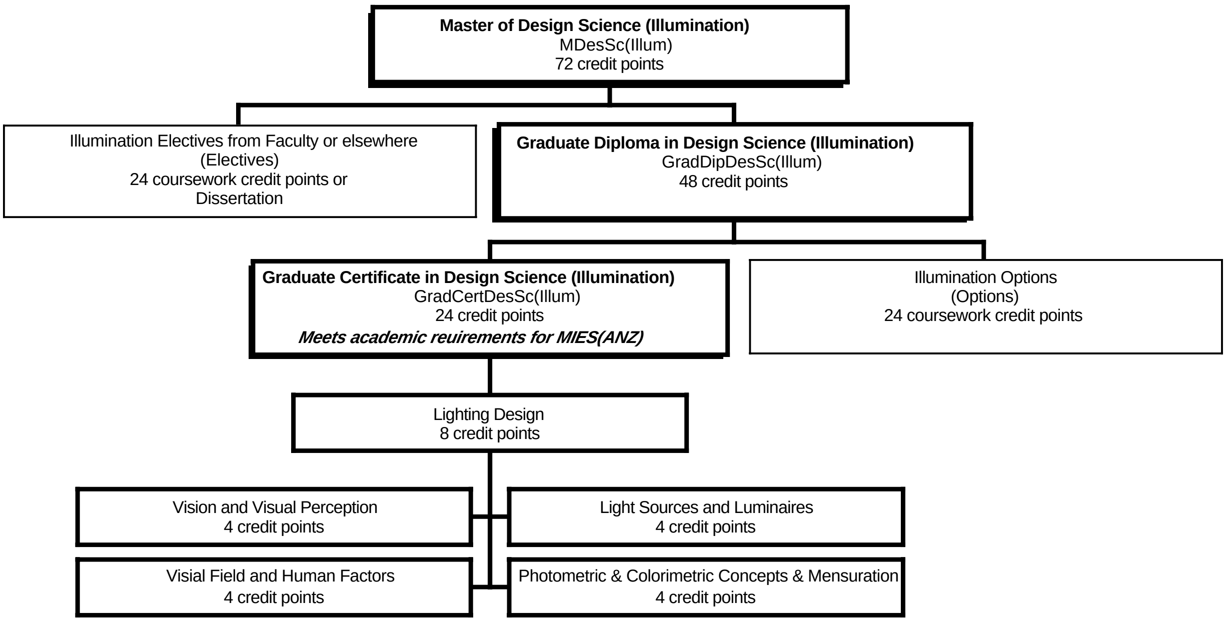
6. EDUCATION IS ESSENTIAL

Competent, responsible lighting design requires people who understand how people react to light as well as the technology of light production, etc. Lighting education, at the professional level, is probably best undertaken as a postgraduate study, building on the general design knowledge provided in engineering, architecture and related fields. An example of such a course, one of the first in the English-speaking world is that at the University of Sydney which has always had a firm basis on both science/engineering and human factors.

6.1 The University of Sydney Programme

The Department of Architectural and Design Science at the University of Sydney has been offering professional lighting education since 1979. There is a Graduate Certificate, Graduate Diploma and a Master of Design Science (Illumination), all of which can be completed by part-time study. Graduates of the program now dominate professional lighting design, illuminating engineering, lighting management and technical sales in Australia. Graduates are also working in Singapore, Thailand, Hong Kong, Indonesia, India, the Philippines and the UK. From 2001 the programme has operated in Singapore with staff from Australia.

Professional Lighting Design Programme Structure



Unit of study outlines are given in the Appendix

The *GradCertDesSc(Illum)* requires 24 credit points and comprises only the core lighting units of study. It is designed for those who want to receive only those units of study required for corporate membership of the Illuminating Engineering Society of Australia and New Zealand (and the use of the designation MIES, subject to meeting the other IES criteria for corporate membership) and to receive an academic award.

The *GradDipDesSc(Illum)* requires 48 credit points.

The *MDesSc(Illum)* requires 72 credit points.

Both the Graduate Diploma and Masters have a mandatory core of 24 lighting credit points. Other units of study can be selected from building services engineering, facilities management energy and design computing areas. The masters can be completed by either all coursework or unit of coursework and a 24 credit point dissertation.

The programmes have an emphasis on lighting design built on a strong foundation of human factors and lighting technology. The mandatory core units of study are: Photometric and Colorimetric Concepts and Mensuration, Light Sources and Luminaires, Vision and Visual Perception, Visual Field and Human Factors, and Lighting Design. Outlines are given below.

The facilities in the Department of Architectural and Design Science and the structure of the programmes allow students to explore not only lighting but related fields. Unit selection flexibility allows students to attempt units of study in other faculties, such as, Engineering or the Graduate School of Management.

6.2 Staff and students

The staff involved in the programmes are the leaders in Australia and are actively involved in lighting education, research, standardisation and international affairs. The author is the director of the programme. Other major contributors include leading academics and practitionersAssociate Professor Terry Purcell, Dr Alec Fisher, Dr Simon Hayman, Mr Steve Furzey and Mr Peter McLean.

Students who take the lighting programmes generally fall into two groups — both are seeking to expand their expertise in lighting. Firstly, those from consulting engineering/lighting design backgrounds and, secondly, members of the lighting industry. Additionally, there have been a number of architects and interior designers who have found the course to be invaluable in the development of specialisations in their fields.

6.3 Entry requirements

Entry to the graduate diploma or masters usually requires a degree or similar but entry is also possible via the graduate certificate. The graduate certificate does not require a degree for entry. Motivation and some preparation such as a trade course or TAFE level lighting course are sufficient. If a candidate wants to transfer to the diploma later, a credit-average (ie 65%) or higher must be obtained in the first year units of study.

6.4 Delivery

The Lighting Design core is delivered in "intensive mode" only. These are usually Fridays and Saturdays, to minimise disruption for employers. Each day starts at 8.30am and concludes around 4.30pm. There are breaks between sections of each unit to allow study and the completion of assignments.

7. FINALLY

This very brief discussions of a few of the issues involved in lighting suggests that it is an important activity that should be undertaken by only suitably qualified, competent lighting designers who can work closely and effectively with other design professionals and clients. Very few such people exist anywhere in the world and a major effort is needed in most countries to improve or, in most cases, to establish professional lighting education. A successful programme structure and method of delivery have also been discussed, where there is a very strong emphasis on human factors, as well as, the more traditional science and technology.

REFERENCES

1. A/NZS1158.3.1-1999 *Road lighting: Pedestrian Area (Category P) Lighting - performance and installation design requirements,* Standards Australia Standards New Zealand, 1999.

2. TC5.12 - Obtrusive Light (*Guide on the limitation of the effects of obtrusive light from outdoor lighting installations*) 7th draft, CIE, Vienna, 2001.

Appendix — Outlines of the mandatory core units of study

Photometric and Colorimetric Concepts and Mensuration **4 credit points**

Outcomes The student will know the basic photometric and colorimetric systems used in Australian and other national and international standards. Students will discover some of the outcomes through laboratory exercises and will demonstrate them in the assignments and examination.

This course introduces the rational system of measurement of lighting qualities and provides the bases for photometric and colorimetric calculations. Topics include: the development of the system of measurement of luminous flux; luminous intensity; illuminance; luminance; reflectance; luminance factor; transmittance; mention of refraction, diffraction and reflection laws; relationships between luminous qualities; basic calculations involved with diffuse surfaces; inverse square law; cosine law; interreflections; Munsell Colour System; CIE Colour System; graphical representation of photometric data; measuring instruments; accuracy; repeatability; colorimetric calculations (chromaticity coordinates Yxy, L*A*B*, Luv, correlated colour temperature, colour rendering indices); the integrating sphere; goniophotometry; distribution photometry. Various measurement and calculation techniques are applied in the laboratory exercises which support the course.

Light Sources and Luminaires **4 credit points**

Outcomes The student will know the bases of light production and the characteristics of practical lamps, how luminaires operate, how to design reflector systems and relevant safety and other standards. Students will discover some of the outcomes through laboratory exercises and will demonstrate them in the assignments and examination.

The various methods employed in the production of light and the performance criteria applied to the sources are discussed. Topics covered include: a historical outline of the development of sources; the practical requirements of light sources; black-body radiation; the sun; the sky; gaseous discharges; electroluminescence; chemiluminescence; incandescent lamps; the halogen cycle; fluorescence; tubular fluorescent lamps; various high pressure and low pressure discharge lamps. Practical lamps are discussed in terms of luminous efficacy, spectral output, colour rendering, life, supply requirements, control gear, cost, etc.

The design, manufacture, testing and the provision of data on luminaires are discussed. Topics covered include: the requirements of luminaires; methods of light control; the properties of optical systems; refractors; reflectors and diffusers; luminance control techniques; manufacture of luminaires and auxiliaries; codes and provision of photometric data for indoor and outdoor luminaires; the calculation of utilisation factors; luminaire luminances; computerised testing; machine readable photometric data. Laboratory exercises will demonstrate some lamp characteristics and luminaires are photometered and photometric data calculated.

Vision and Visual Perception **4 credit points**

Outcomes At the conclusion of the course the student will have a knowledge of the anatomy, physiology and neurology of the visual system related to sight, including anomalies and age-related effects; the processes involved in vision; the distinguishing features of seeing; the physical, psychological and psychophysical processes involved in image detection, figure-ground, colour, form, texture and appreciation. The assignments will allow the student to demonstrate the achievement of this knowledge — some of the work is related to their private environments.

An introduction to the science and art of illumination, examining how individuals maintain contact with and gather information about their environment via their sensory systems, and how this information is dealt with by the brain to create complex perception and awareness of the environment. After a brief general overview of human sensory systems the physiological and psychological processes in seeing are discussed. Topics covered are: the dual nature of light; the physiology of the eye and its musculature; light detection; the visual anomalies; contrast sensitivity; colour vision; adaptation; brightness and lightness. The processes involved in image detection and recognition are discussed including: edge detection; lightness determination; the association of the characteristics of patterns; camouflage; stereopsis; the importance of the visual attributes of tasks, such as alphabets; expectation. Some of the characteristics of seeing are explored in the laboratory, particularly the size-contrast-luminance relationship.

The Visual Field and Human Factors **4 credit points**

Outcomes The student will know the bases of the light-technical recommendations in Australian and other national and international standards. They will discover some through laboratory exercises and will demonstrate them in the assignments and examination.

Development of material dealt with in the course Vision and Visual Perception to examine full-field vision and the human factors involved in lighting the visual field. Topics covered include: the definition of the visual field with regard to size, luminance, contrast and time; the extension of threshold studies to practical task situations; the evaluation of visual tasks with regard to difficulty and complexity; the development of measures of discomfort and disability glare; the illuminance and glare scales used in practical standards; methods for the assessment of tasks and environments; experimental techniques of evaluation, such as multi-dimensional scaling. Laboratory exercises on the assessment of environments in physical and psychophysical terms are used to support the lectures and demonstrations.

Lighting Design **8 credit points**

Outcomes The student will be able to design simple and complex interior lighting using manual and computer-aided methods. The experience will include design for effect and atmosphere. The student will also be able to design exterior lighting for roads, sport and floodlighting. The outcomes will be demonstrated through individual design assignments.

This course brings together the material of the four basic lighting courses to develop the concepts and methodologies of interior lighting design. Topics covered include: the perception of colour, form, pattern and space, and issues relating to the perception and comprehension of the large-scale environment; aesthetics, perception and emotion; the limited quantitative procedures available for use in achieving the foregoing; the practical methods available for predicting illuminances from daylight and uniform arrays of luminaires; the prediction of discomfort; appraisals; codes of practice; economics; maintenance; integration of daylight and electric light.

More advanced methods of interior lighting design follow, including: design appearance techniques; lighting systems; colour and atmosphere-creating; task analysis; choices of sources and luminaires; practical considerations of various lighting situations (e.g. domestic, offices, factories, hospitals, schools, etc.); special applications (stage, television, merchandising, agriculture, etc.).

The requirements for various exterior lighting applications are discussed. Some topics are treated in greater depth (eg various floodlighting techniques) than others (e.g. road, tunnel, aircraft and navigation lighting). Topics covered include: general floodlighting requirements; floodlighting equipment; light distributions; calculation methods; area floodlighting; building floodlighting; road lighting; pedestrian lighting; tunnel lighting; vehicle lighting; traffic signals, airport lighting; navigation lighting; display lighting; advertising.

Various computer-aided design methods are discussed and demonstrated. Assignments based on computer-aided design are used as part of the assessment.