The Need for Lighting Technology Education in Engineering Technology Curricula

Isaac L. Flory IV, PE [1]

Abstract - Artificial lighting accounts for approximately twenty to twenty five percent of all electrical energy usage in the United States. This is surpassed only by the energy consumption of electric machinery. Artificial lighting is a requisite for virtually all activities in residential, commercial, and industrial settings. Whether it is in the area of design, manufacture, application, maintenance, or sales, it is an industry that employs tens of thousands. It is also an industry that has not, from a technological standpoint, progressed significantly during the past fifty years, and a contributing factor to this lack of innovation is a lack of understanding of the technologies involved. This deficit can be partially attributed to a lack of educational opportunities provided at most institutes of higher learning. There are certain institutions that provide varying educational opportunities in lighting, however most of these courses only address a portion of the total technological landscape. The application of lighting is the most commonly available area of study, however insight into the technology that would allow for improvements in lighting efficiency and performance is not a priority in the majority of Engineering and Engineering Technology programs. Coursework could be offered allowing Engineering and Engineering Technology students exposure to the areas of lamp technology, lighting control, ballast design and application, and lighting economics to name a few. This would help an industry that is in need of fresh perspectives as well as more highly qualified employable college graduates.

Keywords: Lighting, Course, Application, Education

INTRODUCTION

In modern times the use of artificial lighting has been taken for granted. When the first incandescent lighting installation was exhibited at Thomas Edison's Menlo Park facility in 1879 it was a revelation and made quite an impression upon those in attendance. Since that time, there have been a vast number of advancements made in lighting technology [1]. There have obviously been improvements in light sources, but there have also been advances in the application of light. These advancements which led to increased popularity of artificial lighting have left modern culture with a luxury that has become a necessity. Few individuals would like to return to the days of the oil-filled lamp, neither from a personal or professional perspective. Our world culture has evolved into a system that requires artificial lighting every hour of every day. Commercial buildings are no longer designed to effectively utilize natural light. Industrial facilities have, through the use of skylights, augmented artificial lighting in certain situations. However, this only is of value for between ten and fourteen hours per day. And certainly everyone acknowledges the importance of artificial lighting in the home. Society's dependence upon artificial lighting is absolute; however the rate of advancements in the lighting industry has slowed since the mid-1960s [1]. There is a perceived lack of technical knowledge among professionals involved in the lighting industry, in part due to a lack of educational opportunities provided at most institutions of higher learning. This paper proposes a solution to this problem by identifying the educational shortfalls and offering a course structure that would greatly enhance the engineering technology student's understanding of the subject. This paper does not consider the area of lighting technology referred to as *stage and studio*. The reason for this is that it does not fall within the category of general illumination. There are many institutions of higher learning that offer extensive educational opportunities in this area in conjunction with performing arts programs.

It should be noted that several statements in this document are made based upon the examination of curricula at a number of colleges and universities. The programs that were investigated were based in part upon lists of ABET

[1] Assistant Professor, Department of Engineering Technology, Old Dominion University, 214 Kaufman Hall, Norfolk, VA 23529, iflory@odu.edu

certified engineering and engineering technology programs, and were researched through extensive use of the internet. Other unreferenced claims are made based upon personal professional experience and affiliations.

From a technical perspective, the science and application of light are vast subjects, much like the areas of electricity and mechanics. Light is energy, and the science of lighting is the study and manipulation of this energy. It is useful to break the subject of lighting technology into three sub-categories; *application*, *manipulation*, and *generation*.

LIGHTING EDUCATION TODAY

Application

Lighting education, as it exists today, is offered through a variety of sources. Most institutions of higher learning that offer programs in interior design or merchandising do offer some level of instruction in the application of light, commonly referred to as lighting design. Topics covered in these courses are likely to include; color concepts, illumination levels, shading or shadowing effects, and the proper ways to incorporate lighting as a merchandising tool. As these programs focus primarily upon the aesthetic, often referred to as the *art of lighting*, the technical level is relatively low compared to conventional scientific, engineering, or engineering technology programs. The topics explored in courses such as these have the most direct impact upon those who live, visit, and work in artificially illuminated environments. In other words, what is taught is what the majority of people perceive as the whole of lighting. As one researches the available literature on lighting, it is apparent that the majority of these publications primarily address the applications of lighting. Since all areas of study there tend to be devoid of certain concepts, the student does not gain a detailed understanding of how the palette of lighting possibilities is formed. As a result they are not aware of the other possibilities that may help reduce procurement and operating costs while maintaining or exceeding the designer's aesthetic expectations.

Institutions offering programs in architectural technology or design often include courses on lighting application since lighting is an important component of building design. As is the case with the interior design curricula, the areas receiving the most emphasis are application and effect. This training tends to be more technical in nature often involving basic illuminance calculations based upon photometric distributions. Here again, there normally is not a heavy emphasis placed upon the creation or control of light, only the end use.

At this point most institutions of higher learning, falling into the two categories previously discussed, do not support further studies in the technology of lighting. To learn more of the specifics of lighting technology the student must either plan on attending one of a handful of universities that offer comprehensive lighting programs, or they must approach a lighting product manufacturer. The president of James Nuckolls Fund has commented that there are only half a dozen institutes of higher learning that have "real" lighting courses [2]. The James Nuckolls Fund was created in 1988 to support college-level lighting programs [3].

Manipulation

The manipulation of light is the process of controlling the luminous output of a light source into a pattern that meets a specific need for a lighting application. As an example, the luminaries employed in sportslighting fall within the category of what the industry refers to as floodlights. Floodlighting is defined as *a system designed for lighting a scene or object to a greater luminance than its surroundings* [4]. The luminous energy is controlled by the use of an optical assembly that is placed in close proximity to the lighting source. The energy is reflected in a way to give a distribution that concentrates the light in a forward direction to illuminate the item of interest. The design and construction of the optical assembly and ballast housing is the responsibility of the luminaire manufacturer. The engineers who create these designs are from various educational backgrounds including engineering, engineering technology and physics programs as well as two-year technical programs. Requirements for designing these products include an understanding of optics, mathematics, heat transfer, and mechanics of materials. Since the vast majority of college programs do not bring these specific areas of understanding together in a single course of study, the luminaire designer likely comes equipped with one or two of these qualifications and attains the balance of the knowledge from work experience. From first hand experience I can claim that the college graduate who is well versed in all of these technical areas would be of great interest to a company searching to fill a lighting position.

Generation

The generation of light, which is the least known facet of the lighting equation, consists of both the light source and the means whereby it is controlled. The man-made generation of light is achieved in a number of ways, but for the purpose of this paper the three of interest are incandescence, luminescence, and electroluminescence [4]. Incandescence is the mechanism by which all incandescent lamps operate and involves the heating of a filament to a temperature where energy is radiated in the visible spectrum. Luminescence is the process behind the function of discharge lighting including both fluorescent and high-intensity discharge. Lastly, electroluminescence covers solid-state light sources which have become a topic of great hope and heated discussion.

Light generation is the most technically challenging of the three lighting sub-categories due to the number and complexity of the components involved. Individuals involved with the technology of light generation may have academic backgrounds in physics, chemistry, materials science, electrical engineering and electrical engineering technology. Lamp or light source design is usually performed by those professionals with graduate degrees, quite often at the doctoral level. Lamp designers are mostly plasma physicists or other technically oriented graduates that have acquired detailed knowledge of their craft while working for a lamp manufacturer.

On the control side of light generation however, electrical designers are in the majority and vary in academic level from the baccalaureate to the doctoral. The technology of lighting control is rooted in magnetics and power electronics and covers ballasts, power supplies, ignition devices and incandescent dimmers.

Manufacturers of lamps and luminaires have offered basic training for many years in the application of their products. The reasons for this are a desire to familiarize the end user with the manufacturer's product offering to bolster sales, and the second more altruistic motive is to compensate for the lack of lighting education available at the college level. If one is willing to invest the time and expense of traveling to a major lighting product manufacturer's location, they can obtain a wealth of lighting information. Training by a luminaire manufacturer will cover lighting sources, electrical requirements, and lighting applications whereas training by a lamp manufacturer is often limited to the production of light and more specifically the production of light using the product that is being promoted at a given time. This is technical information that only makes it to the academic classroom in a few instances.

AN ENGINEERING TECHNOLOGY SOLUTION

All of the technical areas discussed are within the purview of the engineering technologist with the exception of light source design. This is based upon the mathematical requirements for an engineering technology degree as well as a working knowledge of engineering principles [5]. Table 1 categorizes the mathematical skill levels that will be used to illustrate the needs of specific lighting technology disciplines.

Mathematical Level of Expertise	Areas of Mathematical Knowledge
A	Basic Mathematics, Algebra, Geometry
B	Level A with addition of Basic Integral and Differential Calculus
C	Level B with addition of Differential Equations and Optimization Theory

Table 1: Mathematical Skill Level Categorization

Table 2 illustrates the technical areas presented earlier as well as the level of mathematical skill that would be helpful, if not necessary, in the execution of the associated tasks.

PROPOSED COURSE DESCRIPTIONS

A single course, or a series of two courses falling within the category of technical electives in the senior year of an accredited engineering technology program would equip the graduating student with many of the tools necessary to meet the majority of the job functions listed in Table 1. I propose that a one semester course could be effective in conveying the lighting topics listed in Table 3. This information is presented with content summaries and recommended periods of instruction.

Lighting Technical Area	Sub-Category	Mathematical Level
Application	Interior Design	A
	Architectural Design	A to B
	Application Engineer	B
Manipulation	Luminaire Designer	B
	Optical Assembly Designer	B to C
Generation	Light Source Engineer	C
	Control Engineer	B to C

Table 2: Mathematical Skill Requirements for Lighting Technology Areas

Topic of Study	*Proposed Duration of Instruction*	*Content*
The Nature of Light	1 week	Energy, Blackbody Radiation, Spectrum
Color and Visibility	1 week	Vision, Color, Color Rendering, Color Temperature
Basic Optics and Photometrics	2 weeks	Reflection, Refraction, Attenuation, Photometric Distributions
Lighting Terminology	1 week	Definitions and Relationships
Light Sources	1 week	Incandescent, Fluorescent and High-Intensity Discharge Lamps, Efficacy
Ballasts and Controls	1 week	Ballast Operation, Ignitors, Dimmers, System Efficacy
Interior Lighting	2 weeks	Residential, Industrial and Commercial Lighting Applications
Exterior Lighting	2 weeks	Area, Roadway and Sports Field Lighting Applications
Financial Analysis	1 week	Cost of Energy, Cost of Installation and Maintenance, Life-Cycle Costing
Regulatory Issues	1 week	Environmental Regulations and Impacts
New Technologies	1 week	Solid-State Lighting, Induction Lighting, Ballast Improvements

Table 3: Proposed One Semester Lighting Technology Course

A much more detailed coverage of the subject matter could be attained by going to a two course sequence as shown in Table 4. The first course would focus on optical and lighting application topics. The second course would be more directed to the electrical engineering technology student and would cover topics such as lamp characteristics and operating requirements, ballast concepts, and new lighting technologies.

CONCLUSION

In 1991 an organization was founded to promote effective and efficient lighting practice through the use of certification. It is the consensus among many lighting professionals that the need for this organization was partially facilitated by the lack of lighting education at the college level. The National Council on Qualifications for the Lighting Professions (NCQLP) was created through the collaboration of a number of organizations, both public and private, that have a vested interest in maintaining and advancing the level of lighting knowledge. The National Electrical Manufacturer's association (NEMA), the Illuminating Engineering Society of North America (IESNA), and the United States Environmental Protection Agency (EPA) are among the sustaining members that play a large role in the success of the certification program. The certification examination leading to the LC (lighting certified) credential tests for knowledge in the areas of lighting design, assessment of existing installations, financial analysis, installation, maintenance and regulatory compliance [6]. These are all areas of study that could be included in the proposed courses thus allowing for the graduating student to begin their professional career with a professional certification.

Topic of Study	*Proposed Duration of Presentation*	*Content*
Semester One		
The Nature of Light	1 week	Energy, Blackbody Radiation, Spectrum
Color and Visibility	1 week	Vision, Color, Color Rendering, Color Temperature
Optical Design Principles	1 week	Reflection, Refraction, Reflector Designs
Lighting Terminology	1 week	Definitions and Relationships
Photometrics and Testing	2 weeks	Photometric Reports and Photometric Testing
Application Principles	2 weeks	Lighting Application Methods and Criteria
Interior Lighting	2 weeks	Residential, Industrial and Commercial Lighting Applications
Exterior Lighting	2 weeks	Area, Roadway and Sports Field Lighting Applications
Assessment	1 week	Lighting Levels, Measurement, Cost of Illumination
Light Pollution	1 week	Definition, Methods of Reduction
Semester Two		
Electrical Theory Review	1 week	AC Circuits, Power, Power Quality
Light Sources	2 weeks	Incandescent, Fluorescent and High-Intensity Discharge Lamps, Efficacy, Life
Ballast Principles	2 weeks	Ballast Operation, Types of Ballasts, Ballast Life, Ignitors
Lighting Controls	1 week	Incandescent Dimmers, Discharge Lamp Dimmers, Timers, etc.
Regulatory Issues	1 week	Environmental Regulations and Impacts
Criteria for System Selection	2 weeks	System Efficacy, Color Requirements, Maintenance, Operating Cost
Financial Analysis	1 week	Cost of Energy, Cost of Installation and Maintenance, Life-Cycle Costing
Testing and Standards	2 weeks	Lamp and Ballast Testing, Testing Standards
New Technologies	2 weeks	Solid-State Lighting, Induction Lighting, Ballast Improvements

Table 4: Two Semester Lighting Course Sequence

A need does exist for more college graduates that possess lighting technology training. I recommend that a logical location in which to anchor this discipline is within an engineering technology program. The lighting industry has been plagued for years with a diminishing knowledge base resulting from attrition and antiquated design guidelines. The lighting industry needs more professionals, knowledgeable in the whole of lighting technology, so that it may move forward to meet the needs of society now and in the future.

REFERENCES

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Isaac L. Flory IV, P.E.

Isaac L. Flory, IV, served in many positions over a seventeen year period as an employee of Hubbell Lighting Incorporated including Manager of Electrical Engineering and Intellectual Property Coordinator. He has been awarded 25 United States Patents and is a licensed Professional Engineer. He has previously served as a member of the American National Standards Institute C78.4 and C82.2 subcommittees which are responsible for High-Intensity Discharge lamp and ballast standards. He is a member of the Illuminating Engineering Society and the American Society of Engineering Education. Currently he is an Assistant Professor of Engineering Technology at Old Dominion University, teaching courses in electronics, electromagnetics, mathematics, communications and power. He has received B.S. and M.S. degrees in Electrical Engineering from Virginia Tech and is currently pursuing his Doctorate from the same institution (a.b.d.).