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Illuminating Architectural Science: Exploring Metaphors, Models, and the Power of Light

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Abstract This paper explores the intersection of architectural science knowledge and the powerful tools of metaphors, models, and light. By examining the conceptual frameworks that underpin architectural design and the built environment, we reveal the ways in which metaphors and models shape our understanding of space and form. Furthermore, we investigate the role of light in mediating our experience of architecture, from its physical properties to its emotional and psychological impacts. Through a multidisciplinary approach that draws on architecture, philosophy, and physics, we uncover new insights into the complex relationships between these elements and their implications for the creation of meaningful and sustainable built environments.

Index Terms
architectural science, metaphors, models, light, built environment, design

I. Introduction

Original metaphors are akin to unique linguistic unions, diverging from the standardized language code. They thrive due to the abundant opportunities for metonymy within language—where attributes are substituted for the intended object, such as using "crown" for "king." These original metonymic chains typically emerge through cultural convention rather than direct resemblance, often challenging the established norms of language and requiring reconstruction to resolve potential ambiguities [1], [2].

While language is teeming with metaphor, many have become purely figurative over time, deeply embedded in common usage. These "dead" metaphors, like referring to the "leg" of a table, have shed their explicit metaphorical content and are primarily of interest to grammarians and semioticians. However, dead metaphors can still evoke humor, often playing on the interplay of similarities and dissimilarities. This return to the original domain of metaphor can occur intentionally in jokes or unintentional puns, which, despite being considered the lowest form of metaphor, exhibit creativity through the sudden connection of ideas [3].

The ubiquity of lighting metaphors in the English language requires little explanation, with phrases like "to be illuminated," "have the light shine on one," or "be in the dark" being commonplace. Though these are often considered dead metaphors in everyday speech, their usage in lighting education can evoke a sense of recognition, often leading to laughter. For lighting educators, deriving humor from these prodigal metaphors is a standard part of their teaching approach [4]. However, this potential for humor has yet to be fully explored as a broader model for lighting and other architectural science education.

II. Theory Models

In architectural science education, a significant focus lies in conveying specific models that elucidate how and why buildings function, endure, or collapse. While often synonymous with "theory," the term "model" is preferred here for its positive connotation and broader accessibility. Unlike the potentially intimidating nature of "theory," "model" resonates with individuals who may not possess a formal scientific background, as it aligns with common experiences like crafting a miniature house or a sandcastle [5], [6]. In constructing these models, an effort is made to emulate reality, even if in a fantastical manner, utilizing available knowledge, skills, and resources at the time of creation.

These models share many characteristics with scientific models, as both simplify complex realities and highlight key focal points to address perceived main issues [7], [8]. However, scientific models typically exhibit explicit rigor and generality to facilitate broad application, whereas everyday models may embody more implicit and subtle characteristics. Additionally, day-to-day models often contain contextual and symbolic content absent in scientific ones.

The conventional approach to scientific model-making often follows an inductive-deductive pattern, known as the "scientific method." Despite criticisms of its epistemological structure, such as theory-based observation dependence and influences from science's political structure, this method reflects a common-sense mode of thinking. It involves progressing from experiences of particular instances to model generation and application, often employing heuristics as a typical example [9].

Scientific models, by definition, are not reality itself but representations with inherent limitations, as succinctly expressed by Galileo. These limitations include the loss of some information for the sake of utility, the limited domains of models, the necessity of scale factors, and the potential for sub-optimization in optimization models. Additionally, even full-scale models or facsimiles may prove deficient due to changes in context [10].

In model-making, problems rarely present themselves in identical manners or contexts. As precedents investigated become increasingly dissimilar, analogous and metaphorical thinking play crucial roles in bridging model-making gaps. Thus, metaphorical expression is fundamental to scientific discourse, extending beyond the domain of lyric poetry as traditionally postulated [11].

III. Exploring Analogy and Metaphor in Architectural Thought

Analogy serves as a prevalent mode of thought, not confined to the arts but also pivotal in fostering creativity within the realms of sciences and technology. A classic example is the conceptualization of the atom's structure as analogous to the solar system, with electrons akin to planets orbiting a nucleus composed of neutrons and protons, although a strictly quantum mechanical perspective would refute its accuracy. This illustrates a fundamental challenge with analogies—we often cannot ascertain their validity beforehand but only through experiential learning [12]. For instance, early builders transitioning from timber to stone erroneously assumed similar properties for the new material, leading to initial failures and subsequent technological advancements, albeit with remnants of past traditions persisting as "skeuomorphs," such as decorative elements resembling previous functional features.

While linguistic and cognitive distinctions have been posited between analogy and metaphor, for our purposes, they will be treated largely as statements of similarity, as commonly accepted in philosophical discourse. Metaphors extend similarity or, in Aristotle's view, transfer similarity between dissimilar entities. Such knowledge transfer across domains is evident in architecture, like Le Corbusier's mechanistic analogy or Sullivan's biological analogy of "form follows function." While architectural technology examples may seem less common, modeling heat flow via electrical analogies of resistance and capacitance serves as a prominent instance [5], [12].

The interplay of similarity and difference fuels the creative potential of metaphors, with robust metaphors balancing contributions from both aspects. However, as metaphors simultaneously equate and negate two ideas, they navigate a fine line between meaningfulness and meaninglessness. Consequently, for a metaphor to be meaningful, it must be translatable within the current language of usage. In crafting and embracing meaningful metaphors, abstractions are necessary, and details may need to be discarded, akin to the process of model-making. Therefore, all metaphors possess inherent boundaries and can only be extended so far before losing their relevance. When a particular analogy is stretched beyond its limits, it can lead to challenges associated with modernism in architecture, highlighting the importance of maintaining translatability to preserve the metaphor's efficacy within its intended context [13].

IV. Daylighting Analysis: A Metaphorical Lens for Knowledge Acquisition

The utilization of the Daylight Factor Method in daylighting analysis has emerged as the prevailing standard for the past several decades in most regions, excluding North America. It serves as the predominant quantitative approach documented in textbooks, exemplified by works like Koenigsberger et al. It operates on the principles of the CIE Standard Overcast Sky, characterized by its orientation independence, ensuring consistent interior daylighting outcomes for comparable window configurations [14]. The magnitude of skylight reaching specific points within a room is predominantly influenced by the extent of sky exposure, allowing for the estimation of total skylight impact through the integration of all visible sky segments. Consequently, methodologies have been developed to quantify daylight based on spatial geometry.

The Daylight Factor can be conveniently subdivided into three key components:

1) Sky Component (SC)
2) External Reflected Component (ERC)
3) Internal Reflected Component (IRC)

The Sky Component assesses the direct skylight effect at a given point, contingent upon window size and position. External obstructions such as buildings and sun hoods, along with glass characteristics and dirt accumulation, can attenuate this component. The External Reflected Component gains significance in urban environments due to neighboring structures reflecting skylight into rooms. Meanwhile, the Internal Reflected Component gauges light indirectly reaching points through interreflection off room surfaces, influenced by various factors including window size, room dimensions, surface reflectance, and internal cleanliness.

The Daylight Factor (DF) is calculated by summing these components along with correction factors for window and glass types, dirt accumulation, and cleaning frequency [15]:

$$DF = (SC + ERC + IRC) * Cg * Cf * MF$$

Drawing an analogy to knowledge acquisition, direct experience and reflection are key avenues. The Sky Component mirrors direct experiential learning, analogous to unobstructed sky access in open environments. However, structured education often introduces constraints akin to urban obstructions, necessitating reflection on standardized knowledge sources. Yet, the importance of direct experiential learning remains fundamental despite educational constraints [15].

Urban obstructions, analogous to external factors in education, can become significant sources of learning. In educational environments, reliance on standardized knowledge sources corresponds to multiple reflections of direct experience, akin to teachers conveying knowledge from textbooks. However, reliance solely on standardized knowledge can lead to a static educational environment, contributing to student disengagement [16].

Internal reflection, analogous to individual student experiences, shapes learning outcomes. Decisions on learning methods and environments impact students' internal reflections, analogous to decisions on lighting and internal spaces in architectural education. Unfortunately, technological educators often overlook the importance of fostering diverse learning experiences, missing opportunities to enrich students' educational journeys [17], [18].

The modulation of knowledge transmission efficiency varies among students, akin to differing levels of reflectivity and transmission. Knowledge acquisition is often hindered by various constraints, necessitating regular reinforcement to counteract knowledge degradation over time.

In essence, the 'daylight factor' of knowledge acquisition encompasses these diverse influences, shaping learning outcomes. Similar to ongoing advancements in daylighting research, there is a need to explore specific domains of knowledge acquisition in education. However, this endeavor is challenging due to the dynamic nature of education, akin to daylighting conditions, requiring adaptation to varying circumstances.

Daylight factor modeling serves either to evaluate existing designs or assist in ongoing design processes. Similarly, educational design involves modifying existing frameworks to optimize learning outcomes, recognizing the importance of adapting to evolving educational needs."

V. Conclusion

The comparison between daylight analysis and knowledge acquisition sheds light on the multifaceted nature of learning processes. Just as daylighting design factors in various components to optimize interior illumination, education involves a complex interplay of direct experience, reflection, and environmental constraints. Recognizing the importance of both direct experiential learning and reflective practices, educators can cultivate dynamic learning environments that empower students to navigate obstacles and thrive. By embracing diversity in learning approaches and acknowledging the individuality of student experiences, educational practices can evolve to meet the evolving needs of learners in an ever-changing world.

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