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Daylighting Pedagogy:
How can new pedagogic approaches for daylighting enhance opportunities for engaging with daylight in spatial design education?

Gillian Treacy

Doctor of Philosophy

The University of Edinburgh

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Abstract

Experience of spatial design practice (architecture, interior and lighting design) and spatial design teaching in the UK has highlighted a growing dichotomy in the field of architectural daylighting design. A separation is apparent between either quantitative or qualitative daylighting design agendas, growing out of, and characterising divergent Communities of Practice.

This issue is of critical concern as we consider the emergent challenges facing spatial designers. Spatial designers will be expected to contribute to building occupants' health and well-being through the aesthetic and functional requirements of the spatial design, consistently meeting building energy targets and integrating new technological advances into holistically evaluated spatial design proposals. Daylighting plays an important role in meeting these challenges.

Although spatial designers attribute great value to daylit architectural spaces, this study demonstrates that for many architects and interior designers, their use of existing daylighting threshold concepts, lighting tools, definitions and metrics is limited, indicating problematic underlying ontological and pedagogical perspectives. As a consequence of this, the design aims and occupants' spatial environments are compromised.

This thesis therefore asks:

- How can new pedagogical methodologies challenge current ontologies in relation to daylight in spatial design contexts?
- How can these methodologies benefit future spatial design and daylighting agendas?

The thesis outlines these dichotomies, drawing on educational and design process theories and studying the ontological agendas for daylighting prevalent within spatial design educational contexts and practice. It identifies new ways of thinking about daylight needed to address and transform this current situation.

Pedagogical approaches are proposed, based on 'threshold concepts' Cousin (2006), designed to underpin daylighting design decision making and align with familiar 'designerly ways of knowing' Cross (2006). The thesis subsequently challenges,

proposes and explores a dual-ontological approach for daylighting design exploring heuristic methods to assist future holistic design demands.

The study uses recorded task-based workshops to reveal the success of these designed didactics in exposing and supporting relational thinking using selected threshold concepts for daylight. The methods proposed invite simultaneous qualitative and quantitative translational moments through, ‘see’ing, ‘touch’ing and ‘record’ing light.

The research concludes that simultaneous engagement with the dual-ontologies for daylight not only encourages relational understanding of the greater spatial environment but broadens a designer’s perspective of daylighting design and the criticality of its place within future holistic spatial design proposals.

Cousin, G. (2006). An introduction to threshold concepts. *Planet, 17*(1), 4-5.

Cross, N. (2006). *Designerly Ways of Knowing*. London: Springer.

Lay Summary

Through experience in teaching and working as a spatial designer (architecture, interior and lighting design) in the UK, it became apparent that spatial designers struggled to grasp the connections between the ‘numbers’ of lighting and the ‘visual’ appearance of daylighting in spatial design. Consequently, few spatial designers actively engage with numerical daylighting evaluations within their design process.

However, current and emerging design issues with, in particular, sustainability agendas, now require engagement with numerical daylighting verification as part of the architectural design process. This situation therefore cannot be ignored.

Consequently, this research study seeks to find methods for the spatial designer to employ to alleviate these misunderstandings and enhance learning of the connections between these diverging perspectives on spatial design; the quantitative numerical analysis and the qualitative visual representations of daylighting strategies and atmosphere.

Through a proposed dual approach to daylighting (accepting the values of both qualitative and quantitative measures for daylighting), this research study presents a series of task-based workshops in educational contexts investigating the differing techniques to represent and query the behaviour of daylight. The workshops focus on daylight’s relational connections to the elements of spatial design through, ‘see’ing, ‘touch’ing and ‘record’ing daylight representations in varying formats.

The study aims to provide a new pedagogical approach for daylighting design for application to existing and new methods and technologies as they emerge. It investigates current ways of thinking about daylight in spatial design practice and in design pedagogy. It clarifies the need for a ‘dual’ (merged) approach for daylighting pedagogy, inviting simultaneous experiential representations of an interior space, quantitatively and qualitatively. Finally, it advocates for these new approaches to thinking about daylight, gained from a designer’s heightened awareness of the connections between the ‘numbers’ and the ‘visual’ representations of daylight, to enhance the opportunities for daylight to be integrated once again into the domain of the spatial designer.

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Chapter 1 Introduction

1.1 An emerging challenge for daylighting design

> *The history of electric lighting is just over a century old. In recent decades the continued improvements in energy efficiency in lamps has made the substitution and integration of natural light with artificial light increasingly accessible. The direct consequence has been a diminishing awareness of the fundamental notions of natural light.*
>
> *(Traverso, 2015), pp. 15-16.*

The benefits of good quality daylight in an architectural space are undisputed. When discussing light Rasmussen (1964), declares it to be of, "Decisive importance in experiencing architecture" (p. 187). An attunement to the atmosphere created by light within an architectural space is necessary for every spatial designer (architect, interior or lighting designer). This understanding of the fundamental behaviours and character of light, allows some certainty in the prediction of the lit ambience of a space. However, daylight, with its intangible and contextually dependent characteristics, can be difficult to grasp and challenging for spatial designers to work with, particularly as we become less dependent on our surrounding natural environment to provide our primary source of light and heat.

The advent of electric light allowed the early pioneer lighting designers of the 20th century to develop new, ambitious, architectural lighting designs using artificial light sources. Richard Kelly, one of the world's first recognised architectural lighting designers, proposed principles with which to support the nocturnal lighting design of architectural space; "focal glow", "play of brilliants" and "ambient luminescence" (E Kahn, 2011). Through working with modernist architects in 1950's America; Louis Kahn and Ludwig Mies Van der Rohe, Kelly contextualised his lighting strategies as serving the architectural language of the buildings through the experience and activities demanded of the interior spaces (daylight and artificial light) and the relationships between inside and outside environments (daylight and artificial light). Trained in both architecture and product design, his physical 1:1 mock-up lighting scenarios, tested prior to final site installation, allowed for realisation of his ideas using an experiential, qualitative and haptic approach to the technical demands of lighting design.

As artificial light sources grew in type and availability an abundant palette of artificial lighting tools became available for the newly formed profession of lighting design serving the relatively established professions of architecture and interior design. These new tools for architectural expression provided fresh opportunities and approaches to architectural lighting design. It was possible to expand the boundaries of interior spaces through control and choice of light source, luminaire form and reflector design, beam angle, colour temperature and colour rendering. Proposed spatial design solutions were no longer required to engage with location, season, orientation or the dynamic qualities of daylight as artificial light could provide any conceivable lit atmosphere in any location, albeit an 'artificial' atmosphere. Designing with daylight in mind became less of a necessity or priority for spatial design.

> *The idea that building systems alone determine the internal conditions of wellness, concerning both lighting and heating has prevailed… the design culture that has traditionally dictated the connection between a building and its geographical location, form and orientation, is considered superfluous.*
>
> *(Traverso, 2015), p. 16.*

However, it is becoming increasingly apparent that there are difficulties with this decline in the significance of the role of daylighting within spatial design.

> *[The] success of the electrical lighting…has also proven to have some drawbacks. One of these drawbacks is the neglect of the use of daylight – along with a neglect of nature itself.*
>
> *(Volf, 2011), p. 109.*

As emerging contemporary architectural design priorities shift towards addressing 21st-century societal and ecological problems[1] (Sussna, J 2016), engagement with sustainable and human-centric[2] lighting, understanding the effect of lighting on health

[1] The UK Green Building Council's (UKGBC) Net Zero Carbon Buildings: A Framework Definition launched at the Houses of Parliament on 30 April 2019. It is informed by the 2016 Paris Climate Agreement's conclusion that global emissions must be almost halved by 2030, and eliminated completely by the middle of the century. RIBA https://www.architecture.com/knowledge-and-resources/knowledge-landing-page/what-net-zero-carbon-buildings-means-for-practices-and-developers.

[2] "What the people who talk about human-centric lighting mean is lighting that considers both the visual and non-visual effects of exposing humans to light and that widens the range of possible effects from visual performance and comfort to sleep quality, alertness, mood and behaviour with consequences for human health, learning and spending" (Boyce, 2016).

(M Andersen & in Schoof, 2017), (Aries, Aarts, & van Hoof, 2015), (Burnett, 2015), (Gbyl et al., 2017), (Storkerson, 2010), (Strelitz, 2008), (Webb, 2006), and the associated architectural design paradigms and complex systems within which they collectively play a part is now necessary.

An authentic commitment to the understanding of these contemporary design exigencies requires spatial designers to re-engage with daylight to ensure an alignment in their design priorities, addressing Traverso's (2015), "diminishing awareness" of daylighting techniques (p. 16). Yet, for many spatial designers, daylight is no longer a primary tool in the generation of architectural space.

> *But the architects who are designing rooms today have lost faith in natural light. By becoming dependent on the light switch they are content with static light and forget about the endlessly changing character of natural light which transforms a room each second of the day.*
>
> *(L. Kahn, 1969), p. 89.*

The more aware and informed we are about why we experience the light in a particular space we are in, the more we can understand about how this particular environment, its unique context, through activity, over time, has developed its individual sense of place and character. We experience light as atmosphere through our senses and interpret it through our culture and knowledge of our time. Designing creatively with architectural space requires understanding of the atmosphere of spatial environments and daylighting is a significant contributor to the atmospheric condition created within an architectural space (Millet, 1996), (Pallasmaa, 2014) and (Zumthor, 2000). It is therefore necessary for architectural designers to have a heightened awareness of the behaviour of daylight in order to work sensitively, creatively and ambitiously with this qualitative aspect of spatial design within a holistic architectural context.

The benefits of daylight in an architectural space are undisputed. Now more than ever a deeper understanding of the phenomenon of daylight is necessary to engage fully with contemporary holistic approaches within architectural design. Light touches upon many inter-connected elements such as building location climate, orientation, adjacent contexts, spatial volumes, materiality (such as colour, texture, transparency and reflection) and its physiological and psychological effects on users of the space.

If we consider that spatial design encompasses all the conditions of a given space, including what makes it habitable, then that space must be considered in relation to daylight. To create spaces in which people can live comfortably, we must first recognise that human beings are naturally drawn to daylight. If a designed space is to be comfortable and function well, then it must engage with daylight, as a vital component, which is both intangible and invisible (until it hits the surface of an object) yet enables us to see. Daylight is free, yet also “the most enriching of all the materials available to the architect” (Valero Ramos, 2015).

We also experience light physically. Vision is enabled by muscular action and brain function. We need light to perform most of our daily tasks without the pain of glare or strain on the eyes due to highly fluctuating or low light levels. Lighting research has been successfully investigating this aspect of lighting for many years now; as a physiological requirement, how we are affected by light and how it transforms us, through epigenetic modulation[3] (Burnett, 2015). Recently, findings from this research domain have been able to provide quantitative relationships between human physiology and measured light exposure in relation to circadian stimulus, the electromagnetic spectrum of light sources and advanced glare metrics. These findings are dependent on human psychology and physiology, and therefore become important measures for any spatial designer designing spaces with any concern for building users. To design with these parameters in mind necessitates an understanding also of quantitative measures for light.

Human comfort and psychology studies suggest that in almost all situations, daylight within a building gives value to building users (Andersen, Gochenour, & Lockley, 2013), (Aries et al., 2015), [Baker, 2002, Daylight design of buildings] and (Tregenza & Wilson, 2011). The nature of this noted value attributed to daylighting differs through personal preference and geographic locality as cultural and climatic challenges are significant and influential factors (Plummer, 1987). Whilst the position of the sun is intrinsically linked to latitude and time, light from the sky is also related to variable

[3] Epigenetics: "the study of the mechanisms of temporal and spatial control of gene activity during the development of complex organisms" (Holliday, 1990). Epigenetic can be used to describe anything other than DNA sequence that influences the development of an organism and in this case, exposure to light (daylight and artificial light) is under investigation.

climatic and atmospheric conditions, all of which assimilated together create diverse experiential compositions of light and shadow within architectural spaces.

Yet, while our current biological research can evidence the links between light and our spatial awareness (such as the perception of spatial depth or the texture of materials), the changing, dynamic effects under daylit conditions are surprisingly difficult for anyone to predict, designers alike (Rockcastle & Andersen, 2015).

> *While people can observe and assess the visual effects of daylight in a single moment of time, they cannot intuitively comprehend or predict the range of effect that might be experienced over time.*
>
> *(Rockcastle, Ámundadóttir, & Andersen, 2017), p. 2.*

Without an underlying knowledge and perception of the behaviour of daylight and its effects on our environment and health and well-being, the contemporary spatial designer is understood to be ill-equipped to handle the technical complexities and behavioural characteristics of daylight (Benya, 2004), (Galasiu & Reinhart, 2008), (Meek & Van Den Wymelenberg, 2015) and (Reinhart & Weissman, 2012). The architectural communities within which spatial designers belong, whom we would expect to rely upon to supply and apply their knowledge of spatial daylighting design and to grasp, new, emerging design scenarios and demands appear to lack understanding in this area. Other agendas, providing less complex energy savings, fulfilling aesthetic motivations and material practices prevail.

> *A transformation in the architectural design process should be stimulated redirecting attention to the context and the cultural spirit of place, as well as encouraging a sound understanding of the quality of natural light.*
>
> *(Traverso, 2015), p. 16.*

This situation requires addressing urgently. The spatial designer will need to find alignment between their own understanding of daylighting design and the demands of the contemporary construction industry and their future building users. This issue impacts not only on spatial designers in professional practice but also those in the midst of spatial design education. The novice designers forming and defining their own knowledge structures of daylight will naturally bring to future professional design the practices learned through their own prior experiences.

1.2 A contemporary agenda for daylighting design within spatial design – qualitative or quantitative?

In an effort to reduce energy consumption, daylighting research has gravitated towards the widespread development of task-based illumination metrics to assess general illumination thresholds whilst minimizing electric energy use (Reinhart, Mardaljevic, & Rogers, 2006) and [Rockcastle, 2015, Human perceptions of daylight composition in architecture: a preliminary study to compare quantitative contrast measures with subjective user assessments in HDR renderings]. With this current emphasis on quantitative analysis of daylighting and the demands of verification of conformity, for example, LEED (in the USA) or BREEAM (in the UK), a considerable amount of research has focussed on daylighting design through analysis of numerical metrics.

In an attempt to address these issues, only now possible through the rapid technological advancement of computer software, a quantitative, verification-based approach to daylighting design has become dominant. For those designers choosing to engage with this agenda, the approaches that are less easy to verify; the intuitive, atmospheric and qualitative methodologies for designing with daylight, are left behind for the rigour of measurable values.

However, as the understanding and representation of daylit scenarios becomes more numerically complex, as lighting metrics and software gain in accuracy and dynamic range [Tregenza, 2018, Daylighting buildings: Standards and the needs of the designer], it is apparent that spatial designers' engagement with the technological aspects of daylighting is diminishing. Designing spaces with daylight using these quantitative methods has become too challenging for many spatial designers who lack the time and inclination to become fully acquainted with these unfamiliar processes. Daylighting design is therefore frequently passed on to specialists or overlooked as the generator of design possibilities.

Spatial designers are understood to use limited intuitive approaches verified using basic 'rules of thumb' or more complex lighting metrics, where time, budget and training permits (Galasiu & Reinhart, 2008; Lewis, 2017). Without engagement with daylighting software, it is difficult for a spatial designer to establish the dynamic, quantitative, daylighting information required for many larger construction projects and frequently now demanded by clients focussed on conformity with environmental standards.

With the majority of easily accessible software tools focussing on numerical verification, the qualitative ambience that daylight in particular creates in interior architectural spaces is becoming ever more difficult to grasp for the spatial design student and practitioner. Currently readily available daylighting metrics and software give numeric guidance on, for example, predicting lighting levels. However, others are in development (Marilyne Andersen et al., 2008), (Konis, 2017), (Wienold, Kuhn, Christoffersen, Sarey Khanie, & Andersen, 2017). This software is understood to provide indicators to help to successfully visualise a qualitative ontology of daylight, that which spatial designers suggest is most appropriate for architectural design.

Although artificial lighting might be seen to be the easy solution available to enhance building interiors that have been overlooked in their daylighting design, it is clear that artificial lighting does not and cannot match the effects of daylight in a building. Whilst artificial light can be strategically designed to produce an apparently desired qualitative composition, it creates a less dynamic and cyclical experience than that of daylight and struggles to provide the natural "nuance of mood created by the time of day and the wonder of the seasons" (L. I. Kahn, 1990), p.89.

These compositional effects of shadow, contrast, and light directionality are essential to the visual understanding of an architectural space (Innes, 2012), (Millet, 1996), (Steane, 2011), and (Zumthor, 2000). Research findings can confirm that in spaces where daylight is a primary source of illumination, our visual perception of the architectural space is largely influenced by the ephemeral state of surrounding environmental conditions, without which our health and well-being is destabilised (Rockcastle, 2013), and (Burnett, 2015). This research all implies that artificial lighting cannot replace daylight for many reasons. In particular, daylight is perceived differently and thus provides an alternative qualitative experience within an architectural space to that of daylight.

Therefore, if artificial lighting cannot provide all our physical and psychological lighting needs we need to propose a re-engagement with daylighting design within spatial design. However, current daylighting design primarily demands spatial designers to engage with complex quantitative design recommendations and it is apparent that interior designers and architects are motivated to use qualitative approaches only. It is therefore clear there are no easy solutions to address this scenario. Spatial designers are left in a difficult situation between these two ontological perspectives of daylight; 'qualitative' to align with their aspirations for the design project and 'quantitative' to conform to regulations and current industry demands and their own environmental aspirations for the project.

It is hypothesised, through my own observations, that the reason spatial designers engage little with daylighting is due to the complex tools and methods available to verify quantitative design proposals and the lack of available developed, appropriate tools to understand and design with daylight's qualitative characteristics (the ultimate motivation behind many spatial designers' approaches).

A clear gap is therefore evident in both *approach to* and methods *between* quantitative verification of daylighting and qualitative understanding of daylight's distinctive behaviour and characteristics in relation to spatial design. Further, our understanding of light's impact physiologically and psychologically through design approaches and availability of tools to test this has little alignment with the depth of understanding we now have about these issues from scientific research domains.

Daylighting within spatial design serves as a narrative for this thesis. It provides a unique perspective to challenge current spatial design agendas through exploring and establishing the significance of a spatial designer's ability to design with daylight. Initial research is underpinned by my own experiences and motivations crisscrossing between the domains of spatial design; architecture, interior design and lighting design. First insights have continued to develop through the researching and analysis processes undertaken, verified by the research methods employed and challenged by the research participants, their behaviours and motivations.

The purpose of this research study sought to consider the context within which daylighting design is currently positioned within the field of spatial design. It aimed to challenge current siloed approaches in practice and pedagogy through new methodologies for the understanding of the behaviour of daylight. The thesis sought to outline beginnings of new practical and theoretical constructs to progress the learning of daylight within spatial design pedagogy, pulling together the disparate ontological perspectives held within the larger domain.

The research investigation was therefore demanding but necessary; to explore new paradigms for daylighting design aligning with spatial design thinking, and to propose new methods to help transform current epistemological perspectives of daylighting to address contemporary and future spatial design agendas.

1.3 Summarising the Study

> *Some experts say a daylit space must have sufficient daylight but not cause users to perceive glare. Additionally, some would argue that a daylit space must meet a lighting-quality or uniformity threshold. Others are more concerned that electric lighting energy savings are realized and that occupants have not disconnected the daylight sensing lighting controls. In truth, a daylit space is all of this and more.*
>
> *(Wymelenberg, 2008), p. 28.*

This thesis seeks to address the complexity of approaches to these issues. Initial explorations to contextualise daylighting in the field of spatial design are developed through examining both qualitative and quantitative approaches to designing with daylight. The focus of this study considers current integration of relationships of human responses to daylight (qualitative ambience) in parallel with developments in daylighting metrics (quantitative measures) within spatial design. This is investigated through analysing spatial designers' perspectives, exposed by their methods, motivations and concerns when engaging with daylighting design. This study does not aim to promote a new design 'tool' that will provide a solution to the problems discussed. Rather, it examines the current situation through the lens of spatial design pedagogy and places methodology at the core of the study. Findings propose a re-considered approach to daylighting in spatial design, identifying methodologies that seek to address and integrate both qualitative and quantitative motivations equally, as required by future design demands.

The body of research followed sequential steps and these are ordered within the thesis as a chronological process. Starting first with a set of pilot studies, these findings sought to provide a basis for the research questions. Questionnaires were set to highlight and evidence emerging themes from both those in education and those in design practice, allowing for the identification of gaps in daylighting knowledge within the wider research field. With empirical evidence provoking tentative definitions of design motivations and new understanding with regard to daylighting from analysis of the responses to the two questionnaires the research proposal was formed.

First Pilot Study Workshops were undertaken to determine successful research study approaches and provide clarity in direction for the next part of the research. As these pilot studies progressed, research into existing pedagogical approaches was carried out. This in turn fed into the pilot study workshops in an iterative way.

On completion of the analysis of results generated from the Pilot Study Workshops the workshop format, content and methods were re-visited. Now informed with this further basis for the research study the Main Research Workshops commenced. Each week these were analysed and some revisions made to the proceeding workshops. Although this iterative process was time-consuming and required repetition with nuanced changes to format or content the knowledge build up, using this research methodology assisted in a clear framework for the final set of workshops and methods for the recording, analysing and integrating the findings from them.

This thesis explains this process by first reviewing published materials from spatial design, lighting research, and design pedagogy, seeking to span and display the wider context within which daylighting design is situated. The proceedings chapters then develop discussion of the pilot studies, the analysis of existing lighting texts and questionnaires created for practicing spatial designers and design students used to identify discipline specific ontological views of daylighting.

Core explorations for the study were based in educational design studios situated within the domain of spatial (architectural and interior) design pedagogical practice. Further to significant ethical review and design, this context was chosen as it permitted investigations into a designer's early design ontologies for daylight, both existing and developing. Further, it allowed continued, repetitive, observation of any modifications in perspectives as a result of designed pedagogical approaches and/or other influential factors. Within this educational context, the research study was designed to align with the emerging challenge to find holistic design methodologies, shaping design processes and thinking to align with contemporary design demands.

A second set of Workshops were created for the Main Research Study further to these findings, to trial new methods determined by a proposed 'dual-ontological' approach to daylighting. Linkography (Goldschmit, 2014) was used as a basis to develop a framework to suit this new context, the exploration of daylighting design, examine the conversational data in more depth, and determine patterns of behaviour emerging in relation to the Workshop tasks being carried out. Findings from these Main Research Workshops have been summarised and form a proposed pedagogical output as a practical set of workshop tools for teaching daylighting design in spatial design contexts, based on an evaluated innovative methodological approach.

1.4 Defined Research Questions

The chosen research questions seek to interrogate the importance of the contextual field. Further, they aim to expose the varying roles and ontologies that daylighting design can afford within spatial design. The questions challenge my developing rationale for the chosen pedagogical approaches and clarify the relevance of the selected study location, participant group and methods. Finally, they seek to explain the application of the new, proposed, pedagogical tools. The concluding question requires clarity in both the theoretical and practical applicability of these tools and associated methodologies for use in other fields of design and beyond.

- *What role does daylighting currently play within spatial design practice and educational contexts? How and why does this need to change?*

In response to this question, Chapter 2 begins by discussing daylighting within spatial design. The literature review in Chapter 2A investigates the methodological approach of spatial designers and their ontological boundaries as evidenced in their writing about daylight. Current pedagogical approaches for daylighting are then analysed in Chapter 2B.

Chapter 3 provides empirical evidence which identifies the motivations for, engagement with, and limitations of, designing with daylight, as questionnaire responses from spatial design practitioners and students.

- *How can a spatial designer's (practitioner/student) ontology of daylight be exposed and defined through selected research methodologies and methods?*

It was considered of paramount importance to learn of and understand the motivations of designers when working with and designing with daylight in their own spatial design contexts in order to address any issues arising. Again, the Pilot Study Questionnaires provided evidence in answer to this question through examining the scope of engagement with daylight, the current use of daylighting tools and the skill set the spatial designers were understood to have held.

From a review of the language used in spatial design educational textbooks (also in Chapter 3) ontological perspectives of both the writer and the type of the resource were clarified.

- *How can new pedagogical methodologies challenge and change current ontologies in relation to daylight in spatial design contexts?*

This question began to be addressed in Chapter 2 as existing pedagogical approaches were outlined. It was considered important to first review existing approaches before proposing new or revised pedagogical methods. A discussion of the new proposed dual-ontological approach is discussed in Chapter 6 and findings in Chapter 7 outline the successes, proposed revisions and further applications of these methodologies in Chapter 8.

- *How can these methodologies benefit future spatial design and daylighting agendas?*

Chapters 7 and 8 define these new, proposed methodologies and their associated ontologies in relation to the wider field of spatial design. The thesis concludes by proposing further challenges and opportunities for the use of these new approaches in other, related fields.

1.5 Chapter Summaries

1.5.1 Chapter 2: Contextual Review

Chapter 2 seeks to clarify and develop the understood relationships between the human response to daylight (qualitative ambience) and current perceptions of daylighting metrics (quantitative measures) within spatial (architectural, interior and daylighting) design contexts. Contextual considerations for the two domains of lighting ‘quality’ and ‘quantity’, examining the rationale for these prescriptive definitions within architectural design and lighting research are presented. These two domains are introduced to highlight the apparent gap between them and the need for new knowledge.

The characteristics of the tools currently available to assess quality and quantity of daylight are discussed in this chapter also, with explorations into the ontological perspectives for daylight that they align with. First discussions of the distinct ontologies for daylight that exist are initiated here. This review chapter identifies current motivations and ontologies found within the realm of spatial design towards daylight. It seeks to then outline what research study is needed and how to explore and discover new approaches to start to address these current issues.

The second part of Chapter 2 (Part B) provides evaluation of existing daylighting design methodologies. Case studies of lighting design pedagogy are analysed with respect to (a) their methodological approach to “designerly ways of thinking” (Cross, 2011) in relation to daylighting, (b) the format for the understanding of daylighting “threshold concepts” (Cousin, 2006) (Basalamah, 2012) and (c) the ontological approach identified. This is introduced as a review of the limited published case study examples of daylighting (and lighting) pedagogy from design schools worldwide and relevant methodological examples from the wider field to expand the research domain.

1.5.2 Chapter 3: Pilot Study Questionnaires and Textbooks

It was found that little empirical evidence existed with regard to spatial designers’ engagement with daylighting, their explicit ontological perspectives of daylighting or their concerns and issues regarding emergent design requirements in relation to spatial design. This Chapter therefore presents new empirical evidence from a set of questionnaires, designed as part of this research study, to seek insights into the use of current daylighting tools and the daylighting knowledge base in spatial design “Communities of Practice” (Wenger, 1998), further referred to as CoPs. Chapter 3 aims to provide empirical data and further insights into the role daylighting currently plays within spatial design practice CoPs through exposure of ontologies found within questionnaire responses.

Questions were created to extract data regarding relationships between the shifting design priorities and the process of designing to the daylighting decisions made, the designer’s role in analysis of daylight, the tools used for any analysis, the interpretation of daylighting data (visual and numeric) and the role of intuition in making design decisions about daylighting. The final part of this chapter illustrates the need for further investigation into designers' engagement with daylighting design in spatial design practice and proposes pedagogical contexts as scenarios to explore didactic daylighting design tools and methods for their appropriateness to spatial design praxis, and the subsequent engagement and understandings they can afford.

1.5.3 Chapter 4: Methodology

Chapter 4 focusses on the methodologies proposed to address the primary research questions and their role in the generation of the methods used for the study; identifying key contributions from the domain of design pedagogy and the theoretical basis for studio-based pedagogical approaches. This chapter briefly illustrates the need for investigation into designers' engagement with daylighting design in spatial design practice in relation to findings from Chapters 2 and 3. It then proposes pedagogical contexts as scenarios to explore daylighting design tools for their appropriateness to spatial design praxis and the subsequent engagement and understandings they might afford.

Methodologies for the chosen pedagogical approach were selected to align with the exploratory, experiential underpinning of this study. It was considered important to ensure both qualitative and quantitative approaches to daylighting design could be represented through "designerly ways of knowing" (Cross, 2006), understood patterns of design knowledge condition and framing using methodologies to suit "novice" (Gero & Maher, 1992) spatial designers.

This proposed methodological lens invited consideration of aligned constructivist learning experiences, within situated learning environments, allowing participants to re-frame their ontological perspectives. This reflective approach sought to encourage a re- thinking of their design motivations and understanding in relation to the context of daylighting design. The research methods used aligned with an ethnomethodological approach, as defined by Celine-Marie (2011), positioned as a series of didactic tasks in design Workshops using selected pedagogical approaches. This approach allowed for observations of participants within their familiar Workshop studio settings, considered to provide deeper insights than protocol studies in a laboratory environment (Ahmed et al., 2003; Baird, Moore, & Jagodzinski, 2000).

A series of “threshold concepts” (Cousin, 2006) are introduced in this chapter and the rationale for their selection, taken from current lighting theory, is unravelled. These concepts were formed to provide a basis for the didactics selected for the research workshops and are discussed as a conclusion to this chapter and introduction to the next chapter, outlining the integration of these threshold concepts to the workshop methods proposed.

1.5.4 Chapter 5: Pilot Study Workshops

The workshop approach and set-ups are introduced. The case studies and their use in the Workshops is outlined. Further, this chapter seeks to establish a rationale for the creation of participant tasks (relating to threshold concepts), didactic methods, the analysis of the content of each workshop and the expected format of the input and output data. The selected participant groups and ethical considerations are outlined as part of this chapter. The methods developed for the Pilot Study Workshops aimed to specifically expose an understanding of the behaviour of daylight to participants through “situated contexts” (Gero & Kannengiesser, 2004), the differing qualitative and quantitative ontologies for daylight and the tools for designing with daylight.

These workshops were created to test the proposed research methods through the experimental set-up, data recording and analysis methods and insights into the data collected. The pilot study Workshops were intended to test the significance and relevance of the research questions, inform further refined research questions and encourage a focussed framework for the main study Workshops. This pilot study also aimed to explore the scope of the research proposal situated within educational design studio contexts, challenging the possibilities of using selected participant groups and the application of findings to spatial design pedagogy.

Chapter 5 provides further background to the analysis methods chosen for the study; text analysis using NVivo, conversation analysis (CA) and researcher/workshop facilitator observational approaches. This chapter also outlines the observational processes and the expected format of data collection using post-workshop focus groups to encourage and record participant evaluation of workshop experiences. Findings from these focus groups highlight insights into the success of ‘relational’ threshold concepts, inviting further exploration of these in Chapter 6.

1.5.5 Chapter 6: Research study Workshops

Chapter 6 demonstrates a sequence of re-designed Workshop scenarios that build upon findings from the earlier Pilot Study Workshops, suggesting new possibilities for “designerly ways of knowing” (Cross, 2006) about daylighting. The methods used in the Main Research Study Workshops challenge the assumed values associated with quantity and quality of daylighting by integrating and linking design processes through analytical approaches and experiential recall. Each Workshop aims to find distinctive methods for the translation of daylighting concepts through familiar “designerly” heuristic actions and/or design language.

This chapter describes the Workshop format and intent, defined by a proposed ‘dual-ontological’ pedagogical approach and an experimental set-up to “see”, “touch” and “record” daylight. The workshops are then defined around the heuristic actions of ‘Describe’, ‘Visit’, ‘Create’, ‘Model’ and ‘Translate (Visual Lexicon)’ to guide the processes of engaging with daylight on a weekly basis.

A further layer of pedagogical approach is then introduced and applied to each Workshop as ‘daylighting design competencies’, a list of proposed theoretical and practical skills a designer may require to successfully design with daylighting in mind. This list is adapted as appropriate for each Workshop set-up and is described alongside the Threshold Concepts for each Workshop to make explicit the research study expectations with the approach intended.

1.5.6 Chapter 7: Insights

Chapter 7 seeks to explain the results of the Workshops through summarising insights revealed through analysis, examining the data collected. This Chapter introduces Linkoder as an analysis tool using Linkography (Goldschmidt, 2014) and “Function – Behaviour – Structure” (Gero & Kannengiesser, 2004), to categorise and code the recorded workshop conversations. It discusses and demonstrates how a spatial design student’s ontology of daylight can be analysed, defined and occasionally altered by a ‘dual-ontological’ pedagogical approach through analysis of the ‘Linkographs’ produced.

Further, this chapter outlines how presenting appropriate heuristic design actions or moves to novice spatial designers can help engagement with daylighting and encourage a positive approach to new lighting design problems. The heuristic methods proposed are used to develop an integrated 'dual-ontological' approach with each haptic 'action' relating to both a material change (qualitative) and its subsequent affected (quantitative) change in daylighting measurement.

This chapter proposes didactic methods encouraging viewing of the architectural space both numerically and visually. Simultaneously, they can serve as translators between the two ontologies of daylight; 'qualitative' and quantitative'. Combined with 'relational' daylighting metrics and a selection of threshold concepts, this 'dual-ontological' approach is proposed as an appropriate pedagogical methodology for the participant groups within this study.

1.5.7 Chapter 8: Conclusions

Chapter 8 aims to provide conclusions to the questions asked with specific reference to the final research question:

- *How can the methodologies and analysis methods selected for this research study begin to address current and future daylighting agendas in the construction industry and/or reveal other ontological perspectives within architectural design?*

This final chapter seeks to propose how the chosen methodological approach for this study can help reveal a designer's or group of designer's current ontologies and epistemologies using the research study as example, whilst also creating further applications within spatial design and beyond. It points towards further applications within the field of design and construction as an obvious link. Specifically, this chapter also highlights opportunities for application of this methodology in other contexts outside the domain of design, where an abstract concept or an "invisible" phenomenon exists aligned with defined threshold concepts or knowledge domains within a discipline. By proposing a 'dual-ontological' pedagogical approach, encouraging translations between complex and overlapping perspectives with threshold concepts of this character, the thesis seeks to add to pedagogical methodologies in the wider context.

Chapter 2A Contextual Review of Literature

2A.1 Early Observations of daylighting design in spatial design practice and pedagogy.

Architecture depends on light. As light reveals the forms of architecture and the places made by it, it simultaneously reveals the meaning and the intentions that are released through the process of conceiving, designing and building.

(Millet, 1996), p2.

At the beginning of this research study it is important to understand the meaning of 'daylight' in relation to the architectural context within which this study is conceived. The author's prior working experiences in both architectural practice and architectural lighting consultancy provided an opportunity to engage with a variety of different "Communities of Practice" (Wenger, 1998) within architectural design. Importantly it provided glimpses into the distinctive understanding of, and approach to daylighting within each.

From these experiences an initial understanding of the role of daylighting within architecture practice was formed: daylight's role was that of an architectural element, approached practically, in relation to sculptural spatial volumes, fenestration pattern and proportion to suit the programme and aesthetic of the building, and to harmonise with the proposed building elevations.

In architectural lighting practice daylight played an important yet very different role. It provided a steady stream of specialised analysis work through the testing of physical architectural models in an artificial sky and the reading and interpreting of the subsequent numerical test results. This was provided as a consultancy service to architectural practitioners and interior designers in the format of a report suggesting design changes in relation to the results of the analysis.

Having studied and worked in both architectural design and architectural lighting, and informed by these experiences in practice, the necessity for the understanding of both disciplines, one informing the other, was evident within my own epistemological understanding and approach. Yet, it was observed that many architects in practice did not engage with daylighting to any significant level. The interior designers within the team appeared to be even less engaged with daylight, focussing solely on artificial lighting proposals, discounting the possibility of daylight's intervention into the architectural spaces.

Although daylighting was addressed through the design of window and roof apertures, any numerical validations of the 'quantity' of daylight expected within the proposal were left to architectural daylighting practitioners or lighting/electrical engineers within the design team. The question arose as to why it was the case that architects did not engage more with the quantitative daylighting data revealed within their building designs? Surely it was important that the architect was able to understand all types of daylight criteria and therefore be able to take command, or at least influence any further design changes in relation to the overall aesthetic of the building and expected visual perception of the designed space?

Further to ten years in practice and teaching in architecture studio, I began teaching in three separate higher education design courses concurrently; Architecture Technology and Environment (for architecture students), Interior Design Studio and Architectural lighting for Interior Design Students. The similarities and distinctive design epistemologies of each course began to emerge through curriculum content and scope, physical location of the course, students, programme director's and course tutors' expectations.

This is summarised as follows: the architecture students were taught daylighting through the formation of volumetric studies, sometimes context specific, using architectural 'tectonics'[1]. These studies were limited in both time and depth of consideration of daylighting knowledge as many other qualitative aspects relating to materiality, structure and spatial volume prevailed over daylighting. No specific design tutoring or lectures in solar trajectories (affecting sunlight into a space), daylighting metrics or quantitative analysis was given. Students were however given the opportunity to draw lit spaces through introduction to a drawing exercise. The drawing

[1] Tectonics – in this instance this term implies a rigorous consideration of technology, construction and structure giving meaning to the building.

was based on coverage of a graphite square and using a rubber, the student carved light into the space by lifting layers of graphite off the paper.

These same students were given the opportunity to engage with daylighting quantitatively the following year, out with their design studio course, through a course entitled, ‘Technology and Environment’, a lecture course and workshop set. The study of daylighting included a single lecture with a course enhancement of an additional calculation workshop using virtual analysis to examine all the environmental aspects (including daylight) for a case study building. This course was taught separately (physically and theoretically) to design studio and numerical verification of all environmental approaches to the design (sun, wind, heating/cooling/ventilation, energy use and energy in use), were asked to be verified numerically. It was observed during tutorials that students quickly forgot any architectural design aesthetic within their ‘Technology and Environment’ daylighting course when concentrating on quantitative analysis of results. They created generic boxes, conforming with the required numerical results, but lacking spatial awareness or a design for a space that would be pleasant to inhabit. In staff meetings it was confirmed that quantitative daylighting calculations never entered the design studio course. It was apparent that neither course influenced the other in any meaningful way with regard to daylighting design.

In the interior design studio courses the students were exposed to considerably more ‘lighting’ design teaching. In one course, students studied the more general field of architectural lighting one day per week for one trimester in their third year of interior design studies. This included an introduction to daylighting design through presentations of example case study buildings, site visits to observe daylit spaces and basic calculations. However, unlike the architecture course, numerical verification was not insisted upon and therefore few chose to engage with it. Resulting student projects, in most cases, included sunpath analysis through images and discussion of the effects of sunlight into the interior space.

The other interior design course that I was involved in the teaching of provided a seminar lighting series, running for one semester, one morning per week. Within this course artificial lighting was predominant but some daylighting concepts were introduced through presentation of diagrams and visuals of case study buildings.

Students were invited to physically test artificial lighting samples but no daylight modelling was included within this course specifically. Students were however encouraged to test their studio models with desk lamps, representing sunlight as and when they wished, as part of their studio project design process. On observation of this, it was clear that few understood solar trajectories in any detail as the lamps were used to create sunlight from arbitrary, unrealistic angles (and even in some cases from two different angles simultaneously).

It was therefore clear from the pedagogical contexts that I had observed that these different groups of students were being taught daylighting in very different ways. Significantly, the different groups were being taught using differing ontologies for light. In this context these two distinct ontologies are characterised as; a) light as a quantitative measure or b) light as an qualitative, aesthetic addition, to spatial design. Rarely, it seemed, were the two ontological approaches ever balanced or given equal value within a design educator's agenda. It was apparent that the discipline, as architecture, interior design or lighting design, the motivations and ontological perspective of the instructor and the curriculum learning requirements ensured each and every course was different with no apparent shared values for daylighting design.

It was therefore evident from these early observations in design practice and pedagogy that spatial design disciplines were engaging with the daylighting of architectural space. However, for some, this was the minimum required response. These behaviours demonstrated that the differing ontologies for daylight, as taught in design education contexts and reinforced further within professional practice, remained limited and out of sync with emergent design issues. These observations allude to further characterisation of practicing spatial designers' and educators' engagement with daylighting; each with their own methods and approaches to daylighting, with a slightly different agenda informed by their ontological perspective, lacking cohesive understanding, ambition or underlying epistemological approach within the field of spatial design.

2A.2 How do spatial designers engage with the complexity of daylighting in architectural contexts?

Designers are traditionally identified not so much by the kinds of problems they tackle as by the kinds of solutions they produce (Lawson, 2006). The role of the architect[2] as master builder (Burr & Jones, 2010) would advocate for control of all tectonic and aesthetic design solutions, as demonstrated in the fully synthesised, “co-ordinated” (Zanni, Soetanto, & Ruikar, 2014), architectural drawing set/3-dimensional model, including therefore the daylighting of the building within this domain. If, as is considered within this research study, that ‘spatial designers’ include the roles of Architect, interior designer or lighting designer it is important to evaluate the engagement with daylighting these other roles are currently, and are expected to have.

Significantly, it might be argued that interior designers have less of a role to play in the daylighting of an architectural space. They are rarely the generators of the daylit space as their engagement with design decisions pertaining to building armature, location or orientation are limited. However, although the specification of the building envelope is often associated with the architect, the role of the interior designer too may include working with the daylighting of a space through consideration of building apertures to define spatial volumes, partitions, materials, colours and lighting atmosphere within the space.

> *Despite the clear connection to interior environment quality and occupation, the interior designer’s role in daylighting design is not well developed…daylighting practices would benefit from more interior design involvement through integrated design processes.*
>
> *(Theodorson, 2014), p.40.*

Without a designed *integration* of daylight into the interior space, the formal arrangement of the interior and the locating of the associated activities designed to

[2] the term architect was derived from Ancient Greece where “arkhi” meant head chief or master and “tekton” meant worker or builder (Berman, 2004).

take place within it may be ill-informed. Material selection, textures and colours for the space will be less strategically and holistically considered.

The lighting designer, although often only employed by the Architect or client of a design project for the artificial lighting specification, if at all, can provide technical knowledge in the field of daylighting. More often, the lighting designer can use software for analysis of lit scenarios due to working knowledge of terminology and metrics but, critically, they are also able to advise on how technical analysis results can be manipulated in relation to the desired design aesthetic. Further, they can provide useful information that allows smoother integration of the daylighting with the artificial lighting, the lighting control and the selection of materials.

Consequently, it is proposed that it is advantageous for all designers involved with the interior architectural space to advocate for and initiate a clearer and more involved role in the daylighting design of the space. Without the involvement of the interior designer or lighting designer, the opportunity for a holistic architectural proposal is lost.

Other design professionals within the larger design team are also often involved with the architectural daylighting design. This may include the role of the electrical engineer, who may be required to specify the architectural lighting strategy in full, specify artificial lighting and also work with quantitative analysis of daylighting. Decision making with regard to daylighting may also be guided by a specialist environmental engineer or designer. Their role is often, though not exclusively confined to, the energy savings daylight can provide to a project and this professional may get involved with siting of the building and/or placement of apertures and solar control.

Additionally, the building management teams running larger buildings are also involved in the specification of daylighting, through the daylighting control, window blinds management and the subsequent programming of sensors, blinds and artificial lighting time clocks. Their connection to the building users, sometimes also the client, is an important one, known to be one of the most important factors of a daylighting design strategy working successfully in a building (Galasiu & Reinhart, 2008), (Christoph Reinhart, 2014) and (C Reinhart, 2018).

These practices may not directly align with the common understanding of the boundaries of specific disciplinary agendas as they overlap with the assumed scope of the architect, interior designer, environmental engineer/designer or architectural lighting designer. The importance of this relationship of different design groups engaging with daylighting design to affect interior space highlights the common misconception and understanding associated with singular and hierarchical 'disciplinarity' of practitioners within the built environment field.

The term 'discipline' is often understood to suggest singularity of purpose and action, such as, '*disciplinarity*' (Nicolescu, 2001). However, it was clear from experience in practice that designers across a broad range of disciplines (both architects, interior designers and electrical engineers) were working with daylight in their projects with diverse and occasionally opposing purposes manifested in their discussions and outputs. These 'purposes' could be further defined as their motivations for their engagement with daylighting, whether qualitative (visual aesthetic purposes) or quantitative (numerical verification). When working with daylight within their projects they chose to engage in varying degrees and this engagement and purpose was revealed in a variety of formats; visual, numerical and/or written.

In design practice, it was observed that some architects used daylight as a tool within their rendered images and others, such as the lighting designers, calculated the expected lighting levels and provided a report on the suggested formal changes to the building envelope. In each of these situations, daylighting engagement was expected to fulfil a different purpose or priority, and was, by no means, expressing any clear singularity of purpose, even within the same discipline. The author assumed, at this early stage in the research, that this engagement was dependent on the particular client or student cohort and specific project demands. However, on reflection, it became apparent that these moments of engagement with daylighting related not simply to the practical demands of the project brief but also reflected an approach to daylighting that was value based, derived by the designer's design beliefs and influenced by the context within which they were operating.

In each of these situations a shared value was apparent with others in the design practice within which they were based and a shared understanding was evident as these drawings and reports were seen to be passed around an office as shared working documents within sub-groups with multiple authors e.g. architectural renders, analysis of calculation results and written daylight reports. This shared understanding clearly relates less to the discipline and more to the "Community of Practice" (Wenger, 1998), within which a designer might align their self.

2A.3 How do "Communities of Practice" affect spatial designers' ontologies and epistemologies of daylight?

By reflecting on these differing practices, I observed that the role daylight played within these varied contexts was clearly diverse, sometimes unique and perhaps dependent on the value daylight was given by the "Community of Practice"' to which they belonged. The term Community of Practice (herein referred to as CoP), was first known to be used by anthropologists Jean Lave and Etienne Wenger. They identified a distinctive community that served to act as a "living curriculum for the apprentice"(Wenger-Traynor, 2015), p2, during their investigations into apprenticeship as a learning model within working environments. The "Community of Practice" within which the apprentice worked not only provided shared methods of working but also shared values in the work taking place.

It is understood that in many disciplinary contexts such as those from the built environment listed above, shared commonalities can be found that may serve to define the CoP to which they belong (Wenger, 1998). Wenger's (1998) model of a CoP identifies foundational characteristics that are inherent in any CoP; "a shared domain or interest area" implying a commitment to the domain, and therefore a shared competence that distinguishes members from other people.; an identifiable community through, crucially, the development of "a shared repertoire of resources: in short a shared practice" (Wenger-Traynor, 2015). The methods by which a group of designers identifying with a CoP engage with daylight is therefore likely to be broadly similar, shaped by the shared repertoire of resources, the characteristics of those scenarios and the subsequent 'value' they are afforded by the CoP.

It is important to avoid any misunderstandings of this term in that the theory of CoP does not always relate directly to the disciplinary name given to the practitioner. For example, the author observed architects with an interest in daylighting to a greater or lesser degree, although under the same job title they had differing design priorities and values with respect to the daylighting of a space and their role in the creation of this aspect of design. With an apparently shared disciplinary approach and label of “architect” they were not all belonging to the same CoP as they did not necessarily share the same values within and for design. I suggest that it is the designer’s ontological understanding through previous design applications that motivates the approach a designer takes to daylighting design

The spatial designer’s ontological perspective, as understood in this situation, is therefore defined by; the designer’s alignment with sets of design concepts, structures and categories in the domain of spatial design. Further, in this specific context, a designer’s ontological understanding of daylight and its applications will include its known properties, its characteristics and how we perceive them, and the relations between these.

Whilst each designer’s ontological stance towards daylighting will therefore be different, I also observed that frequently, designers within the same design studio, did share the same design priorities. This occurred when a design studio was led by a director with a particular epistemological perspective of architectural design. An epistemological perspective in this context is thus different to the ontological approach in that it is understood to set out:

- a designer’s beliefs about design (and in this case, daylight)
- how the designer discovered knowledge about those beliefs
- why they place importance in this knowledge

Therefore, in this thesis a designer’s epistemology is defined as the encompassing source of a designer’s identity, knowledge of their specific design practice and their basis for this knowledge.

This epistemology is subsequently understood to influence and inform the design ideas filtered down through the management structure of a practice to all designers involved in the project, through informal mentoring (I suggest as guidance on knowledge and beliefs) and apprenticeship (learning about the importance of this knowledge by copying and doing). Therefore, although an epistemological perspective is understood to individually held, it is proposed that an architecture or interior design studio in practice or in an educational setting may create its own CoP and associated knowledge structures (epistemologies).

In educational settings the academics involved in the teaching of any of these architectural, engineering or building management professional disciplines will inevitably engage with daylight to some extent. Often connected to the academic institution or laboratory, researchers involved in the domain of lighting and daylighting ultimately seek to challenge current understanding and develop new methods and approaches for design. This is often led by priorities associated with new knowledge in other related areas; a reaction to challenging environmental design efficiency and energy demands or new understanding in the psychology or physiology of human interactions with daylight.

Their research, although often relating closely to design scenarios and the users of architectural space, is rarely disseminated to architectural design practice. Instead new findings are more often confined to CoPs that identify with lighting or environmental design research journals or conferences. This overlooks practitioners in other CoPs and ultimately reduces the impact, influence and (evolution/advancement) of any new findings within the larger, and more general design domain.

Although significantly successful conferences such as the Velux Daylight Symposium aim to include a full range of built environment disciplines within their speakers and attendees, it is apparent that the engagement of anyone other than those who are local to the event is limited to those involved in the built environment interested in daylighting research. Conveniently, much of the conference is published on-line, but again, many spatial design practitioners are unaware of the opportunities available in accessing this, or have time to examine it carefully for design insights.

Although the example above illustrates only one, single observation of the general misalignment of dissemination of findings that exists between research and practice it is known in the wider domain that it is becoming a growing problem. Whilst research produces new findings and tools about and for daylighting that affects spatial design and future building inhabitants, many spatial designers are seen to persist in their design practice and teaching aligned with their own, pre-formed, ontological perspectives for daylighting, based on their CoPs understanding of the current status quo. They remain unaware of new findings that appeal for daylighting design to be addressed in a much more informed, holistic and human-centric way to align with emergent issues within spatial design and the increasing known complexity of daylight's relationship within it (M. Andersen & in Schoof, 2017), (Burnett, 2015) and (Solt et al., 2017).

In summary, my experience as a spatial design practitioner (Architect, interior designer and lighting designer) and lecturer has informed my understanding of daylighting design within these specific contexts. Observations and experiences have alluded to a lack of, or engagement with, daylighting design in a routine, integrated manner within spatial design contexts. Rather, daylighting has become the responsibility of the lighting specialist or engineer to verify that the proposed spatial design aesthetic, "works" (through numerical verification). This limited perspective for daylight is most likely influenced by social and cultural contexts, educational background and nurtured by the Communities of Practices within which the designer belongs. I have identified that these restricted ontological perspectives that designers engage with, through discipline, pedagogical curriculum constructs and their CoPs, plays a critical role in the lack of a holistic perspective of daylighting design I have observed in spatial design practice. This can only be seen as problematic for the changing practices of spatial design today and in the future.

This Chapter aims to outline these perspectives and approaches, beginning, in Part A, by exploring these initial insights further; the different perspectives for daylight, shifting design agendas and the associated complexities for spatial designers when working with daylight.

2A.4 How can the complex nature of daylight be understood by those engaging with it in spatial design?

> *Our lives are intimately bound up with light. We literally cannot live without it. It is one of the basic immutable forces of nature. Light is a primary element, animating life here on earth.*
>
> *(Millet, 1996), p.1.*

The amount and quality of daylight we get is almost completely determined by our built environment. Like our cities and buildings, light is also shaped artificially; it is a social product, an expression of our cultural inheritance. Consequently, we need to consider our relationship to daylight through a cultural lens. The spatial environments we engage with provide the framework for our daily lives, but it is individual behaviour that determines the amount of daylight actually received, and an individual's physiology and cultural make up that modulates the characteristics of the lighting information we acquire.

Solt and Volf, Architects and researchers in the field of daylighting design argue that it is also our cultural background that determines our need for, approach to, and appreciation of daylight. In a world with so many people on the move, the cultural background of the users cannot automatically be assumed from their geographic location; in multicultural societies, different needs and approaches coexist and must be taken into consideration. (Solt et al., 2017), p28. In order to understand the importance of daylight, and to define criteria for implementation of any research agenda, we must understand all of its implications. The cultural aspects of daylight encompass two important facts:

1. As cultures around the world differ, cultural identity and hence the culturally based needs of individuals will vary depending on their context. In this sense, these needs are relative, which means that appreciation of daylight to some extent is culturally determined.
2. As humans are fundamentally cultural beings, our cultural needs are essential even if they are not as primarily vital as our biological needs; within a defined context, the importance of those cultural needs is absolute in that they must be taken into consideration, especially when designing human habitats.

(Solt et al., 2017), p28

If the aim of this research study is to find methods for spatial designers to achieve an expanded, 'holistic' epistemology of daylight, that spans the current separated ontologies observed, we need to ensure that designers develop an understanding of the characteristics and behaviour of daylight to use within an integrated approach. Consequently, the spatial designer needs to understand the range of ontologies for daylight, the value of each and their appropriate application for each new design problem. However, it is understood that this is a challenging situation to address, as, holding a holistic epistemological perspective for daylight requires engagement with ontologies that are not currently aligned, and, demands a new, "heterogeneous skills set" (J. Mardaljevic, 2016), to fulfil these demands.

Daylight can be difficult to work with, and although solar geometries defining the sun's path can be determined in advance, the appearance of the sun at any time of year, the weather on any particular day and the result of this on the interior atmosphere of a building can be difficult to predict.

> *The Architect can fix the dimensions of solids and cavities, he can designate the orientation of his building, he can specify the materials and the way they are to be treated…Daylight alone he cannot control. It changes from morning to evening, from day to day, both in intensity and colour. How is it possible to work with such a capricious factor?*
>
> *(Rasmussen, 1964), p.186.*

Therefore, in this research study focussing on daylighting design, we must be accutely aware of the role of daylight and the complexities associated with its use in spatial design as well as its cultural, biological and design meanings affecting a designer's epistemology.

From my own observations and the views of the daylighting specialists alluded to above, as a basis for this study, it is proposed that these 'complexities' associated with the understanding and application of daylighting design knowledge can be found in both of the two broad ontological perspectives for daylight within architectural contexts; quantitative and qualitative. Consequently, the first set of discussions within Chapter 2 Part A, focusses on the quantitative ontological perspective for daylight; where it can be found in spatial design, current demands, modes and methods of working with daylighting (within this ontological perspective) and future requirements.

The second part of Chapter 2 Part A, seeks to define the qualitative approaches and ontological understanding relating to this perspective currently demonstrated by spatial designers and theorists. The idea that emergent design issues within spatial design, with regard to daylighting, requires addressing through this ontological perspective is proposed and questioned. This section also aims to highlight discoveries found within this qualitative, 'measured' approach, demonstrating valuable insights into overlapping of knowledge and ontological domains for daylighting. In conclusion of Parts A and B, a summary highlights key findings from the literature review, identifies further research required and points towards *ways between* the disparate current ontologies for daylight as found in published papers and pedagogical approaches to date.

2A.5 Why do emergent issues for daylighting within spatial design demand a quantitative approach?

> *In the twenty-first century, the horizons of our fundamental experiences have expanded and continue to expand. We experience and think differently.*
>
> *(Holl, 2000), p.13.*

Current discourse on daylighting within spatial design has been dominated by performance- based, energy-related concerns, since the energy crisis of the 1970s and slowly “strengthened by the shift toward sustainable building practices” (Kjell, 2014), and S. F. Rockcastle, Ámundadóttir, & Andersen, (2017). Over the past decade, because of concerns about global climate change, expectations regarding building performance to reduce energy use have resulted in a resurgence of the importance of daylighting within spatial design.

> *In terms of societal cost, it is much cheaper to reduce energy use through design and retrofit (sometimes referred to as nega-watts, as a play on mega-watts) than it is to increase energy production. For this reason, informed building design is one of the least expensive pieces of an overall strategy to minimize energy use and associated climate change.*
>
> *(Kjell, 2014), p. 13.*

However, as future design agendas relate to sustainability and flexible design notions this current global situation necessitates sustainable design parameters and verification. Many countries and international organisations have initiated rating systems to assess sustainable construction. Some examples are United Kingdom’s BREEAM (Building Research Establishment’s Environmental Assessment Method), USA’ LEED (Leadership in Energy and Environmental Design), Australia’s GREEN STAR, Japan’s CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) and Germany’s Passivhaus (Passive House Institute Darmstadt), (Zanni et al., 2014).

With energy compliance top of the agenda it can be argued that the spatial designer must now expand their skillset, “think[ing] differently” (Holl, 2000) p.13, to include methodologies that engage with these quantitative analysis approaches. Yet, spatial designers, balancing many other design project concerns, have little time or motivation to develop the complex quantitative daylighting skills now required of them (refer to Chapter 3 for details of these insights from practitioners).

This call to “think differently” concerns a spatial designer’s knowledge and their approach to this knowledge, questioning current epistemologies. However, it also can be understood as propositional through requiring changes in current ontological arguments in design, from those that were predominantly qualitative to quantitative.

Compliance with zero energy demands, however challenging, cannot be ignored. Future projects will demand more and more verification of daylighting through this approach, informed by quantitative ontologies.

Dean Hawkes (Hawkes, 2008) in his book “The Environmental Imagination”, suggests that there is indeed a place for an ontology that considers the quantitative “physical facts” within spatial design and it is an intrinsic part of any spatial design project. He proposes:

> *The ability to envision the outcome of the conjunction of form and material, set within the physical facts of the climate and locale, in ways that inform and enhance the purpose and meaning of a building…lies at the very heart of the architectural project.*
>
> *(Hawkes, 2008)*

In summary, it can be recommended that we must seek to broaden spatial design ontologies to respond to these increasingly demanding quantitative daylighting requirements. This might include alternative approaches, multi-ontological perspectives or new tools, but critically, has to fit with the unique and distinct character of spatial design problems and design process in order to be of value to the spatial designer through “enhance[ing] the purpose and meaning of the building” (Hawkes, 2008) underpinning their epistemological beliefs.

2A.6 Introduction to Quantitative Measures for Daylighting

We understand that, “the properties of light are dual: it is both a particle form and a wave form” (Millet, 1996), p.2. Light can therefore be measured, quantitively. Measurement of light has developed over many years, improving with accuracy and scope for both the daylighting and artificial lighting of architectural space. Current ratings systems, such as those mentioned in the previous section, rely on these measures for quantitative results to verify compliance. These measures for daylight take the form of a variety of metrics and corresponding recommended numerical values for different spatial typologies e.g. classroom or public lobby. Checking their spatial design proposal using daylighting metrics allows a designer to attempt to define the quantity of daylighting they can expect in their designed space(s).

The first notable recommendations and legislation for daylight can be found within early twentieth century British law with the principal of Right to Light. Mardaljevic, in (P. Tregenza & Mardaljevic, 2018) describes this as an “easement provision under the Prescription Act of 1832 to ensure the owner of a building with windows that had received daylight for 20 years or more has a right to this light”. This prevented the construction of a building or obstruction close by interfering with the existing amount of daylight illumination.

Additionally, various tools were developed for the purpose of measuring daylight including tools by Townend (1931):

> *This instrument determines mechanically the illumination at a point on a horizontal surface due to the direct light from the sky visible at that point. The illumination (Daylight Factor) is read off from a small integrating wheel.*

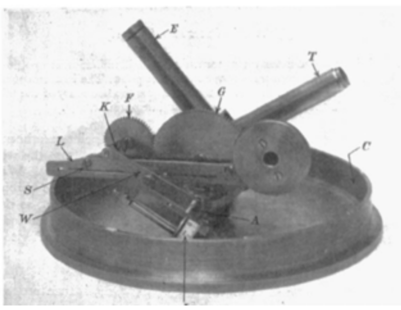

Figure 1 Daylight Mesuring Tool (H. C. H. Townend, 1931), p. 12-13.

A developing “no-sky line” methodology was also underway and a comment by Waldram in the Lancet of 1934 confirms this:

> *An international agreement was reached in 1931 to the effect that at all such positions the light (no view of the sky) is definitely inadequate for ordinary purposes such as clerical work over reasonably long periods, except under very exceptional and temporary conditions.*
>
> *(Waldram, 1934)*

Lighting metrics have now been in place for many years, available for spatial designers to use when designing with daylight since the 1940s in the UK. The Building Research Station (now known as the BRE) developed design aids to help with the design of daylighting and the carrying out of daylighting calculations to suit the available metrics of the time. An example of this is the BRS daylight protractor for calculating Daylight Factors in wartime Britain where a particular fenestration pattern of longer length to height prevailed:

> *The computation of daylight factors is becoming increasingly common in spite of its complexity. Simple protractors are described which facilitate such computations, and are suggested as being particularly useful in factory design.*

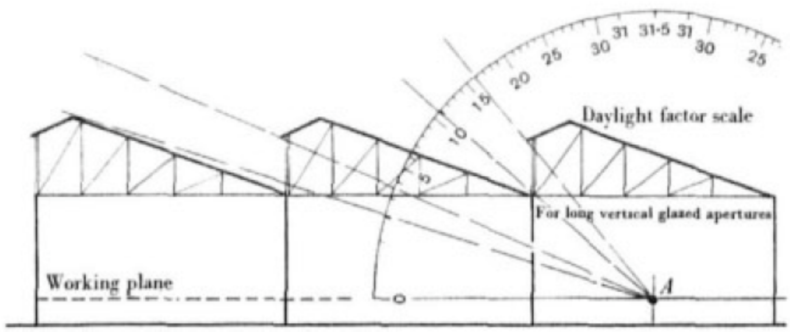

Figure 2 Computation of Daylight Factors (Dufton, 1940)

From the diagram above, taken from guidance notes for architects, we can appreciate the development of the method at that time, to allow analysis of daylight using physical drawings through tracing angles and shading diagrams to help with Right to Light calculations and the Daylight Factor (DF). These early metrics were primarily concerned with the achievement of quantities of light at particular points within a room.

In Addleston's RIBA Research Award report (1972), "An investigation into the teaching of light and related human response in twenty schools of architecture in the United Kingdom in 1967", he talks of these daylighting metrics as being, "simple to use without very much knowledge of lighting" (Addleson, 1972), p89. However, he was aware that the qualitative aesthetic of the daylight in the architectural space could not be addressed using this approach as he commented, "intuition was still required after the aids had been used" (Addleson, 1972), p89. Addleson's observation suggests that the quantitative values that the metrics produced did not provide sufficient information, in a holistic sense, for the designers using them. It is not clear what information was missing but it was apparent that intuitive decisions were still required for a complete daylighting design.

Often originating from these early concepts, daylighting metrics have continued to develop, for example, through the recommendation of a minimum level of daylight in a space, defined by the amount of area of a room receiving a given level of light and/or a view of the sky. Additional illuminance metrics were developed to analyse minimum threshold levels in task-oriented spaces such as offices, libraries, and schools (Lam 1977). Whilst these thresholds are now understood to be controversial in their definition of recommended upper and lower levels of daylight (as we now know more about the non-visual effects of daylight), they were established to ensure that adequate illumination could be measured and achieved across a given task surface for a given activity (IESNA 2000).(S. Rockcastle, 2013).

Daylighting metrics are now an integral part of daylighting design that is continuing to develop through research activities such as practitioners' post occupancy evaluations (Burkhart, 2016), (Day, Theodorson, & Van Den Wymelenberg, 2012) and academic investigations into the physiological effects of daylight in spatial design; (Andersen, Gochenour, & Lockley, 2013), (Aries, Aarts, & van Hoof, 2015), (Boyce, 2010), (Volf, 2011), and (Webb, 2006). In the UK, legislation allows local authorities to establish their own daylighting guidelines in accordance with British Research Establishment (BRE) and British Standards (BSI) recommendations, working in most cases to demonstrate minimum "acceptable" (P. Tregenza & Mardaljevic, 2018) daylighting standards to ensure reasonable environmental conditions. The following section outlines these metrics and discusses the approaches required to engage with them.

2A.7 What challenges face the use of Daylight Factor as the ubiquitous daylighting metric?

Current daylight metrics can be divided into three main categories: illumination for task-driven performance, visual comfort for task-driven performance, and occupant preference toward the field-of-view. (S. Rockcastle, 2013), p12. Current methods and metrics to evaluate and quantify (day)light include measures of the amount of light such as illuminance [lux (lx)], daylight factor (DF), and daylight autonomy (DA); potential glare, including luminance (candela per square meter, cd/m2) distribution in the field of view or derived values such as the daylight glare probability (DGP), daylight glare index (DGI), vertical illuminance, and unified glare rating (UGR); and perceived colour of light expressed as the correlated colour temperature (in kelvin). Some of these metrics, like the Daylight Factor (DF), are typically static and theoretical metrics. In this section, the Daylight Factor metric is discussed to introduce the variety of spatial design factors considered when using daylighting metrics and the methods employed.

The daylight factor (DF), incorporated into the British Standards in 1949, is still the principle metric used in guidance on daylighting in the UK (Lewis, 2017) and is the most "ubiquitous" (S. Rockcastle, 2013) for measuring daylight in a space. This metric measures the ratio between indoor and outdoor illuminance[3] under overcast sky conditions (Moon, 1942), The perceived benefit of the daylight factor was that it permitted daylight levels within buildings to be "assessed on a reasonably scientific basis, putting daylighting on a more rational basis than hitherto" (Great Britain. Central Housing Advisory, 1944). It was originally created to estimate daylight access from a 'worst-case' perspective (Reinhart et al. 2006) while avoiding the

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[3] *Illuminance, is defined as the total luminous flux that falls on a surface, per unit area (CIE 1926). It is the foundation upon which most other task-driven metrics such as daylight factor and daylight autonomy are based. Codes and standards most commonly reference illuminance measurements across a work plane to determine the amount of light recommended for various tasks (IESNA 2000).*

difficulties associated with fluctuating sky conditions and the dynamic nature of sunlight (S. Rockcastle, 2013), p13.

The 1964 British Standards encouraged the use of photometric methods to measure daylight factor in existing buildings or models. These methods included the use of photometers, such as the BRS Daylight Factor Meter, or cosine corrected photoelectric cells that could be connected through an electrical circuit to a metering instrument such as a microammeter (Lewis, 2017), p.1163. The use of models was only really effective when used in conjunction with an artificial sky, as the brightness of natural skies constantly changes making it difficult to obtain accurate readings. The major advantage of photometric methods was that they enabled simultaneous measurement of direct and reflected light (Lewis, 2017).

The daylight factor was one of the first metrics used prior to any digital computation methods. The calculation of multiple absolute values was therefore laborious and unpractical. The inherent simplifications that many would view it now to have were, back then, a “necessary expediency”(J. Mardaljevic, Wilde, B and Davies, A., 2011).

The average daylight factor (ADF) equation was first proposed by Lynes in (1979), no longer demanding laborious multiple single point calculations. The equation was revised by Crisp and Littlefair in 1984 following validation tests using scale models (P. Tregenza & Mardaljevic, 2018). It is usually expressed as follows:

$$\tilde{DF} = \frac{TW\theta M}{A(1 - R^2)}$$

Where DF is the average daylight factor; T is the effective transmittance of the window(s); W is the net area of window(s); the angle in degrees subtended in vertical plane by sky visible from the centre of a window; M is the maintenance factor; A is the total area of bounding surfaces of the interior; R is the area-weighted mean reflectance of interior bounding surfaces.

Whilst we can see from the list of factors above that daylight factor uses many aspects of the spatial design to determine the daylighting measure (through the variants in the formula), the DF can also be taken as a “measure of the *connectedness* of the internal space to the outside, whilst also accounting for the reflectance of internal surfaces”

(P. Tregenza & Mardaljevic, 2018). In this sense it provides *relational* daylighting information.

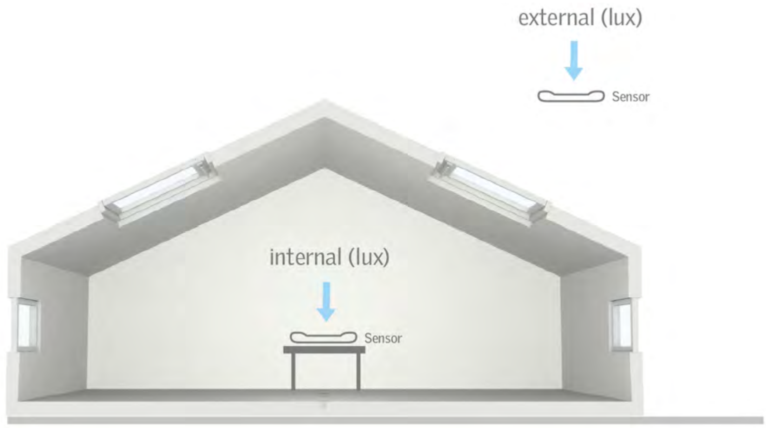

Figure 3 Source: Velux – Drawing showing the values measured by the daylight factor method - simultaneous reading of the internal and external (unobstructed) horizontal illuminance levels.

The measurement technique evolved over time and the threshold values recommended vary drastically, from O,1 DF to 10 DF (0.001-0.10 of outdoor illumination) depending on occupancy type, regional lighting expectations, and historical time period. DF is relatively easy to measure, is conceptually clear (as discussed above), can be considered point-by-point or as an average by space, and generally is consistent over time regardless of the amount of illumination outdoors. However, it is limited in use to overcast sky conditions, and therefore has “garnered heavy criticism and is no longer considered a viable metric in abundantly sunny climates” (Wymelenberg, 2008).

Being that DF emerged from the UK's predominantly overcast skies, it should be no surprise that it does not work well in sunny clear sky conditions (Wymelenberg, 2008). This metric does not consider sunlight from clear sky conditions or even room or building orientation. With a suggested minimum value of 2% DF, overheating has been known to occur because orientation has not been considered. This metric, if analysed in isolation can verify a spatial design proposal for a room that will provide sufficient daylight but in some cases an “unbearable overheating” (Kisilewicz, 2015) due to solar gain. The metric in itself is not wrong but clarity in understanding (i) its application and (ii) its rationale for use within the spatial design process becomes necessary to understand. Daylight factor prediction therefore does not provide a solution to the larger set of daylighting criteria demanded as daylighting is a much more complex phenomenon than the quantitative issue a daylight factor calculation can address.

If spatial designers choose to calculate with and use the “Illuminance on a working plane”[4] types of metrics, often considered important to allow for the integration of artificial with daylighting strategies, we must ensure the appropriateness of the application, the rationale for the use of the metric and its shortcomings are understood. “It is not just the total quantity luminous energy” (P. Tregenza & Mardaljevic, 2018) that defines the daylight in a space but the need to acknowledge the patterning and dynamic nature of daylighting itself. For example, if a designer chooses to consider the illuminance on a working plane for a specific climate, location, date, time and space they can predict the sunlight patterning and daylight level (in Lux) for a specific point within a room. However, this is a single static state, a snapshot of a predicted second in time and gives little away regarding future conditions due to the behaviour of daylight.

This dynamic characteristic of daylight simply cannot be computed by hand calculations or protractors with any degree of accuracy. It involves much more complex computer methods to achieve this type of data. The advent of computing systems has allowed large amounts of data to be explored and calculated. This has changed daylighting metrics considerably over the last 10 years as the dynamic variation of light that characterises daylight can now be explored, measured and predicted with increasing accuracy. This next section outlines the capabilities of this approach and the methods and skills required by spatial designers for its use.

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[4] *In most cases, daylight factor levels in rooms are measured at work plane height (e.g. 0.85m above the floor), leaving a 0.5m border from the walls around the perimeter of the work plane.* [*https://www.velux.com/deic/daylight/daylight-calculations-and-measurements*](https://www.velux.com/deic/daylight/daylight-calculations-and-measurements)

2A.8 How can dynamic daylighting tools assist spatial designers' engagement with daylighting design?

The use of analogue daylighting tools that exist as methods within architectural design practice and education as discussed in the previous sections grasps on to the historically valued epistemology of craftsmanship; of drawing using physical models and tools to measure, represent and understand our daylit environment.

However, in the last two decades, we have experienced an emergence of more complex surface geometry and a renewed sense of delight in the interaction between elements of the natural and built environments. Categories of architectural form have grown increasingly more diverse as geometric modelling software and parametric forms have liberated the designer from a dependency on flat or regular surfaces and modes of fabrication (Zarei, 2012). The result of this liberation includes some highly dramatic and articulated spaces whose interaction with direct sunlight brings the question of contrast visual perception to the foreground of any discussion on daylighting design (S. Rockcastle, 2013), p5. Additionally, digital technologies are providing progressively more efficient and precise verification of these complex lit architectural interior spaces through 3D computer modelling of virtual environments and calculation software.

In architectural and environmental building design, engagement with digital tools is now commonplace. Building Information Modelling (BIM) through 3-dimensional modelling tools allows information to be exchanged between design team members. As data sets have grown, this has allowed design teams to work with current and expected (future) climatic data sets. These data can be closely matched to a specific weather station location and the associated expected daylight through climate files (climate-based daylight metrics, CBDM), allowing for more accurate location and orientation dependent daylight predictions.

As daylight is a highly dynamic source, the complexity of predicting performance necessitates a method that can "evaluate a space over time and across diverse sun positions to communicate the variable impacts of light and shadow" (S. F. Rockcastle et al., 2017). Daylighting metrics can now include this dynamic variation of light successfully using digital calculation methods. Due to the density of data required to run this type of calculation, computer simulations are now commonly used to calculate or predict these metrics. Simulation is a powerful tool for evaluating these performance dynamics as it is possible to “assess a range of temporally-induced effects” (S. F. Rockcastle et al., 2017). Therefore, with renewed emphasis in daylighting providing the benefit of improved well-being for inhabitants and the advancement of computer climate prediction, spatial designers have a larger than ever set of tools available to them to design with daylight, theoretically.

Existing tools are most commonly only used to assess illumination and glare risk. However, new climatically and temporally sensitive metrics, categorized as dynamic daylight metrics, have been developed to provide a pathway forward. The most significant of these are daylight autonomy (DA) and useful daylight illuminance (UDD). These metrics use site-specific weather files to calculate daylight performance over an entire space grid. Further, they allow for analysis of the expected daylight (at chosen threshold levels) over a longer period. Over which time the space can be analysed for attaining a “useful” level of daylight for the tasks required and for the percentage of the space reaching that target through the year.

This climatically considered, dynamic understanding and appreciation of daylight provides a distinctly alternative approach to analysing light, exposed and expressed through the use of the analogue draughting tools. Significant value is now given to accuracy in numbers and large data sets by those involved in research in the area as energy efficiency, lighting efficacy and solar gain can all be designed with digital tools to easily provide highly predictable data defining energy usage and compliance.

However, it is apparent that the understanding and representation of daylit scenarios is becoming more numerically complex as lighting metrics and software gain in speed, advancing in their accuracy and dynamic range. The increasing variety of tools, outputs and competencies and their understanding in use now demands an “eclectic and heterogeneous skills set”(J. Mardaljevic, 2016). Further, an underlying knowledge of the characteristics of daylight is needed to use the tools available effectively.

Using digital tools for simulated daylight analysis output data can be straightforward with appropriate training and, even without training, data can be generated very easily. The resulting data outputs are known to be prolific, generating hundreds of data points, tables and charts, mean and median averages but often simply used as evidence to determine lighting levels. This quantity of data is in itself a challenging task to unravel for analysis, particularly for the spatial designer with little experience.

Further, it is commonly known that the results can be highly inaccurate as they are heavily reliant on the accuracy of the 3D computer models used for the analysis (Christoph Reinhart, 2014), p38. The resulting data, further to calculation processes may not be correct due to input inaccuracies in the numerical values of 3-dimensional models created for the exercises, or the 3-dimensional model does not represent the space under analysis appropriately (through material choice, gaps in the model between drawn/modelled planes, lack of adjacent built context or fenestration details).

> *It remains crucial that the architect understands the outcome of a daylight analysis so that he or she can consider the results during further design iterations.*
>
> *(Christoph Reinhart, 2014)*

2A.9 Which Daylighting Metrics are designers expected to engage with?

> *As designers, we are trained to place value in the concept of spatial experience; however, we are increasingly asked to quantify our design intentions in terms of net energy balance.*
>
> *(S. Rockcastle, 2013)*

Quality and “uniformity of experience” (Juhani Pallasmaa, 2005) in interior spaces is becoming codified to ensure regulatory compliance or follow guidance notes where practical. From a review of UK standards and discussions with designers from other countries out with the UK (Velux PhD Symposium 2015 and 2017) and their published papers it appears that not all legislation is consistent. There is an apparent varied emphasis on particular regulations relating to one or two aspects of daylighting requirements in each country with occasional regional diversity also. Further, it is also evident that some regulations demand historically established analysis techniques with little or no reference to current lighting research findings and values.

> *Some regulations require absolute values of illuminance, others retain the daylight Factor (DF); some consider sunlight, many appear to ignore the particular climate of a place.*
>
> *(P. Tregenza & Mardaljevic, 2018)*

(Galasiu & Reinhart, 2008), (C. F. Reinhart & LoVerso, 2010), (Christoph Reinhart, 2015) and (Tregenza, 2018), highlight the range of available metrics that designers working with daylight might choose to use to demonstrate conformity with the standards. For the spatial designer, the methods available to demonstrate conformity with the standards of each particular situation are diverse. Some scenarios, dependent on the country the designer is based in and the building typology that they are working with, require hand calculation and protractor methods and others a full virtual environment climate-based daylight modelling (CBDM) analysis[5] to be undertaken.

We only need examine the Local Government planning or building control daylighting guidelines in the UK to find evidence of this. This degree to which regulations are required to be followed or enforced in Scotland (the area with which this study is focussed) is directly related to the local authority within which the building is located. A survey of information that individual councils provide taken from six sample councils was conducted in a "Survey of design guidance issued by local planning authorities in Scotland which may inhibit appropriate sustainable design solutions Report" - Michael Jones, Cambridge Centre for Housing and Planning Research, Department of Land Economy, University of Cambridge and the findings were summarised as follows:

Issues of daylight, sunlight and overlooking can be expressed as geometric rules, and in general local authorities had adopted more or less detailed policies with a view to maintaining adequate daylighting and sunlighting standards and maintaining privacy.

The degree of prescription tended to vary according to whether the local authority was essentially rural or urban, with Highland Council at one extreme apparently having no specific guidance, to Edinburgh Council at the other with three advice notes including a twenty-eight page booklet on daylight and sunlight. It is interesting to note that Edinburgh's guidelines were the most comprehensive containing a large number of

[5] *Climate-based daylight modelling (CBDM) is the prediction of any luminous quantity (illuminance and/or luminance) using realistic sun and sky conditions derived from standardised climate data. CBDM evaluations are usually carried out for a full year at a time-step of an hour or less in order to capture the daily and seasonal dynamics of natural daylight. Developed in the late 1990s, CBDM steadily gained traction – first in the research community, closely followed by some of the more forward-thinking practitioners. CBDM was pioneered, independently, by Prof Mardaljevic and Prof Christoph Reinhard (MIT). https://www.lboro.ac.uk/departments/abce/research/rei/cbdm/*

diagrams illustrating the 25 and 45 degree rules of thumb, together with the 43 degree rule of thumb for assessing impact on adjoining undeveloped sites.

It seems the quantity of guidance given reflects the difficulty of building in central Edinburgh in particular with Listed buildings and dense urban fabric. This is the only local authority guidance on this topic to mention (in passing) that software now exists to carry out the necessary modelling. All others referred to the BRE guide which works with the traditional hand protractor methods for calculating sun and shadow angles, developed more than 50 years ago and are currently still available to purchase and use:

A daylighting assessment, where appropriate, will be carried out in accordance with the British Research Establishment publication – 'Site Layout Planning for Daylight and Sunlight, a guide to good practice' – P.J. Littlefair, BRE Bookshop, British Research Establishment, Garston, Watford.

Additionally, much of the guidance is aimed at non-professional applicants, and contains very basic advice, such as:

A few helpful pointers to remember:

- *The sun rises in the East and sets in the West.*
- *The sun reaches its maximum height around Noon and will be due South at this time.*
- *The sun is a lot higher in the Summer than the Winter and days are longer.*
- *In Scotland, the sun elevation in mid-Winter does not generally rise above 10 degrees and therefore casts long shadows.*

Stirling Council - Development Advice Note: Daylight, Sunlight and Privacy (2004).

In viewing the documentation available on the sample local authority websites, it became apparent that design 'guidance' or 'rules' were scattered across a wide variety of documents, ranging from Structure Plans, through Local Plans and draft Local Development Plans, to more specialised documents, sometimes issued as Supplementary Planning Guidance, but often issued simply as advice to the development industry or to individual householders. It also became apparent that were significant ambiguities and difficulties in identifying whether a ‘rule’ was a ‘rule’, or whether it was ‘guidance’ or merely ‘advice’. Additionally, it was proposed that there was a lack of application of these metrics in design practice because the purpose for the use of daylighting metrics was limited in daylighting design guides and texts.

Prior to publication of the current Edinburgh Council daylight and Sunlight guidelines the draft paper was sent to Edinburgh Architectural Association members for comment. They raised the following comments that are summarised here, identifying current perspectives of the time (2010)[6].

Architects were concerned about the increased technical competency needed because of the time it would take for proficiency in the understanding and carrying-out of the daylighting analysis. Further, they were concerned that it would be necessary to employ specialists to do this work. Any suggestions of 3-dimensional modelling analysis were rejected by the council as “overly onerous”.

Therefore, this evidence suggests that even although increasingly accurate dynamic lighting tools are available they are still demanding time and motivation on the part of the spatial designer to engage with them on any useful level. They can assist the spatial designers with numerical verification but this is of little help if the set-up provides incorrect data and/or if the output values are not understood. The next section summarises the demands placed on spatial designers in the local context of this study, and the approaches they encourage.

[6] Edinburgh.gov: Planning committee 25 Feb 2010.

(i)

Comment by architect:

Concern over length of document and elaboration of technical rules resulting in more need for specialist consultants

Answer:

The documents has been in reduced in scale as a result of the section on average daylight factor calculations being removed. ***The diagrams should help designers*** *to achieve reasonable standards of daylight etc.* ***without recourse to specialist*** *consultants for most planning applications.*

(ii)

Comment by architect

We hope that the ***alternative geometric approach to complex calculations*** *will minimise the amount of additional work that may be needed to prove that the guideline has been followed. Perhaps more consultation on this is needed once v* ***see how this actually affects architects and other designers****?*

Answer:

The ***geometric approach to daylighting*** *has been incorporated* ***rather than calculations****. The guidance will be subject to yearly review.*

(iv)

Comment by architect

The greater ***use of 3D modelling*** *should be encouraged.*

Answer:

Applicants can submit 3D computed models in support of their applications. It was not considered appropriate to make this a mandatory requirement of the guidance since most applications can be assessed without it and therefore this could be ***an overly onerous requirement****.*

It has become too simple to calculate light as ‘energy’ and not understand the implications of the results. With the majority of easily accessible software tools for environmental analysis focussing on numerical verification, the ephemeral and embodied ambience that daylight in particular creates in interior architectural spaces is becoming ever more difficult to grasp for the design student and new architectural design professional (Treacy, 2015). It is apparent that daylighting design as a generator of interior ambiance may soon become a lost art in the face of numerical verification and lack of its application or meaning.

> *Advances in these metrics to accommodate climate-based sky conditions and occupant behavio[u]r have improved our ability to evaluate task illumination and glare, yet the same attention has not been paid to evaluating positive perceptual responses to daylight.*
>
> *(S. F. Rockcastle et al., 2017)*

Although these complex data can provide some guidance on task lighting levels, this information still provides little indication of the lit ambiance of the architectural daylit space. Rockcastle, an academic carrying out work in this area notes that “there are few if any dynamic simulation-based methods for evaluating the perceptual aspects of daylight composition or its potential effects on architectural design” (S. F. Rockcastle et al., 2017).

Researchers Solt and Volf comment in agreement that:

> *The demands and parameters of these factors are not handled by most of these metrics, resulting in an unfortunately still rather incomplete picture.*
>
> *(Solt et al., 2017), p.28.*

2A.10 Why are qualitative daylighting approaches alone problematic for the concerns of spatial design?

When considering the "value" of daylighting standards and, if applicable, the need to analyse architectural proposals to demonstrate compliance, the metrics used to demonstrate this conformity must therefore also be considered if they are to be used and assigned value. In theory and practice the metric used should relate closely to the standard being analysed and provide valuable information for the designer using it.

The very character and purpose of light is dependent on a set of design principles which are revealed to the observer through experience, and not through a planar map of illumination levels.

> *No matter the tool used, the metric providing the resultant numerical value is based on a mathematical construction, not a physical luminous quantity. Herein lies the difficulty in attributing value to metrics that need to coincide with the design process within architecture that is unequivocally, visually and physically informed.*
>
> *(P. Tregenza & Mardaljevic, 2018)*

This idea highlights the need therefore to consider metrics that provide the most obvious connections to an architectural space. Further, Tregenza (2018) proposes that,

> *Describing lighting only in terms of illuminance is equivalent to describing music in terms of sound pressure level. Such specification may be necessary during (a single step of) the design process (for verification), but as a description of the experience is woefully inadequate.*
>
> *(P. Tregenza & Mardaljevic, 2018)*

When considering the metrics available it becomes clear that our connection with daylight, and the scenario that architectural designers wish to address comes much more from the visual and physical appreciation of an environment. Although many of our codes and recommendations are concerned with task-based illumination levels, “occupants are attracted to the visual diversity of their surroundings”, establishing the need for new metrics that can quantify and place value in these perceptual qualities (Rockcastle, 2013), p2. While there is some agreement on the minimum amount of illumination that is required for the human eye to perform visual tasks within a given space, there is little consensus on how much contrast or brightness makes a space visually appealing (Rockcastle, 2013) or achieve the atmosphere the designer wishes to create.

The apparent difficulties for designers when working with daylight metrics and standards can be demonstrated in the work of those currently involved in daylighting research. Leslie (2012) provides a challenging list of parameters that the software he and his team were developing at that time would be required to address. The differing parameters and measures included in his software proposal reveal the complexity and difficulty in finding appropriate architectural solutions to fit with recommendations:

> *No prevailing metric has emerged to help identify buildings that are well-daylit buildings. This paper proposes a ‘daylighting dashboard’; a visual representation of a design’s potential to meet eight design goals: average illuminance, coverage, diffuse daylight, daylight autonomy, circadian stimulus, glazing area, view and solar heat gain.*
>
> *(Leslie et al., 2012)*

Further, if we consider closely the number of issues included when we attempt to define parameters for daylight quality we have further evidence of this problem:

> *Let me posit that a daylit space provides daylight as (i) the primary source of daytime illumination to accommodate the occupants' visual demands, (ii) is experienced as a visually and (iii) thermally comfortable place (iv) connected to outdoor phenomena, and (v) persistently maximizes electric lighting energy savings while (iv) minimizing peak energy demand.*
>
> *(Wymelenberg, 2008).*

It is therefore evident that there is no one, developed, standardised tool that achieves a clear result that embraces all the concerns associated with designing with daylight, often described within metrics as daylighting criteria. By design this definition does not state how much daylight is necessary to accommodate the occupants' visual demands or what constitutes visual comfort. A definition that is specific enough for a particular space type will be useless for a general application. This is precisely why daylight is so challenging to understand and to successfully design into buildings.

With such an array of daylighting analysis tools, regulations and recommendations a range of issues arise. With regulations and recommendations each focussed on one particular part of daylighting analysis e.g. illuminance on the working plane the necessity to fit solutions around this goal can detract from and in some cases compromise or even jeopardise other aspects of the daylighting strategy and holistic building design values. Tregenza suggests that mandatory standards can be “crude tool(s)”, with their application resulting in overall spatial and lighting conditions “quite different from those intended”, for precisely this reason.

CBDM techniques are becoming increasingly more common as authorities, schools and large-scale contractors aim to achieve analysis results with improved accuracy and verification. Further, if we use these tools with the aim of achieving a more accurate estimation of lighting levels the need to improve the accuracy of the architectural model (physical or digital) is crucial as the output values will only be as accurate as the model. That is to say, if we include furnishings and fittings within the interior of the space and allow for realistic reflectance values of walls and floor materials we are able to predict with more accuracy what the lighting levels for a space might be. Otherwise, the “output values relate to the overall volume or shell of the space and do not relate to the significant impact of furniture and people causing a constant dynamic adaptation of the environment” (S. F. Rockcastle et al., 2017).

In summary, it is clear that the large range of tools that can be employed to measure daylight emphasises the fact that no one tool has “universal acceptance”. This is evidenced through the variation of different tools, daylighting regulations and recommendations still in use throughout the world. Daylighting metrics have only gained momentum in the last decade because of the increasing concerns that existing illumination-based metrics are not addressing light as perceived by the building user. Any attempt to deal with daylight in spatial design holistically, both qualitatively and quantitatively, through consideration of the wider context and agendas, is unfortunately still relying on disparate sets of tools and parameters for quantitative verification of daylighting supplemented by a designer’s intuition and experience.

Within the field of architecture, it is essential that we couple daylight performance criteria with design intent and provide metrics that address visual, perceptual, and task related criteria (Rockcastle, 2013) p9. Therefore, the next section of the thesis outlines findings from physiological studies regarding daylight’s effect on humans and the complexities in these findings in relation to spatial design.

> *Becoming more fully aware of the extent of our biological complication, whose underpinnings reach deeply into the sensory-emotive world that we daily inhabit, is simply a first step in this process”.*
>
> *(Mallgrave, 2010), Introduction.*

2A.11 What knowledge about the characteristics of daylight can be gained from the domain of physiology and psychology?

> *[The] designer must not only understand the physics of light, but also the physiology and psychology of light perception by humans.*
>
> *(Steffy, 2002)*

Lighting research has been exploring our perception of daylighting and artificial lighting in architectural space for many years. In many instances these investigations have been developed as an attempt to find daylighting criteria that could serve to provide information on daylighting design for architectural spaces grounded in empirical approaches using human physiology.

Natural light has a spectral composition that provides the most preferable visual conditions for humans. Bringing daylight into buildings can provide illumination sufficient for working activities during most of the day, reduce use of artificial lighting and therefore electricity demand, positively impact visual performance, and allow for the diurnal movement of light and shade that can subsequently influence aesthetic appreciation of interior spaces. With advancing construction technologies and the use of artificial lighting, air conditioning and elevators prevalent from the 1960s onwards, it was possible for buildings to become larger, taller, and deeper in plan. Consequently, screened off from daylight, many building users spend their days in artificially lit spaces, neither enjoying the amenity or health benefits of daylight nor directly aware of the presence and position of the sun in the sky (Solt et al., 2017).

Although human beings are resilient and appear able to cope with extreme variations in environmental and living conditions, this process of separation from natural daylight and our external environment can have negative impacts on health and well-being (Solt et al., 2017). Daylight influences virtually every aspect of human physiology and acts via three main routes: (1) visual, (2) direct skin absorbance, and (3) nonvisual ocular actions on the circadian clock in the brain and on other neuronal pathways. Although the visual role is obvious for spatial design and understood by all the non-visual effects of light can be more difficult to understand. However, scientific research can now provide us with empirical evidence of its role in human health and well-being.

The non-visual role of light is our powerful cue, resetting our circadian pacemaker that regulates hormonal rhythms, alertness, and cognitive performance. Our individual circadian rhythms are influenced by our exposure to daylight (Andersen et al., 2013), (Barroso & den Brinker, 2013), (Boyce, 2010), (Rea & Figueiro, 2016) and (Volf, 2011) and as such access to the right amount of daylight, at the right time of day is seen to be crucial to physical health and well-being. Darkness too plays a part in our well-being, the primitive and poetic charm of the night: its obscurity, today threatened by artificial light and by a rhythm that knows no lights and shades (Griffero, 2014). Some examples of this can be seen in the work of (Hauge, 2015), identifying humans circadian relationships to the sun and the necessity for daylight for well-being. Empirical studies that clarify human behaviours with and without sufficient daylight (Drosou, Mardaljevic, & Haines, 2015) and (Gbyl et al., 2017). The design of the architectural space can directly influence the penetration of daylight and hinder or promote application of these research findings.

Further, we are now fully aware of the many principles of our vision.

> *We take light that enables us to see for granted, but we are dependent upon it in more ways than we perhaps know, psychologically as well as physiologically*
>
> *(Millet, 1996), p.1.*

The physical and psychological characteristics of each person's visual system modify luminance perception. In bright, outdoor conditions, an eye's pupil physically constricts, the retina becomes desensitized to luminance, and photoreceptor pigments undergo chemical changes. Depending on the precise way in which the visual system adapts, the brightness of a particular luminance will be perceived differently. The luminous effect of daylight depends on a number of variables, including how a particular viewer's eye physiology interacts with the intensity and angular distribution of direct, diffuse, and ground-reflected solar energy components, as modified by the specularity and reflectance of receiving surfaces. (Solt et al., 2017). Visual comfort depends on our perception of light, which encompasses physiological sensations and functions as well as emotions. Thus, visual comfort is more than the "absence of discomfort" or glare, and is determined by optimal light quality and quantity for specific tasks and individual needs. It also interacts with other stimuli such as temperature, noise, and air quality.

Visual comfort is typically assessed by subjective evaluation of a lit environment, and in a few cases also by physiological measurements such as electromyography of eye muscles, pupil size, and cortical excitation. Together these studies reveal that visual comfort is highly variable and depends on:

• The light quality (e.g., brightness, intensity, spectrum, flicker frequency, contrast, luminous distribution, dynamics, angle of gaze, perception of room space, aesthetics, scenery, and window size).

• The characteristics and state of the individual (e.g., sex, age, medical history, visual ability, circadian phase, duration of prior wakefulness, prior light history, mood, and cultural conditions).

• Work-related conditions and living circumstances (e.g., work tasks, stress, socioeconomic status, and social relationships).

(Solt et al., 2017), p20.

With focus on research into these personal responses to daylight, the necessity to consider the impact of discomfort glare[7] and the requirement for new indices to measure this (Fotios, 2015), (Lin et al., 2015) and (Wienold, Kuhn, Christoffersen, Sarey Khanie, & Andersen, 2017), has been the focus of much recent research in the field of lighting. It is now apparent that daylighting criteria can only sit within a range of parameters as specific needs vary from person to person [Tregenza, 2018, Daylighting buildings: Standards and the needs of the designer].

We also understand that our vision always adjusts to a given level of light, and it is only able to perceive "momentary differences in brightness" (Volf, 2011). At any given time, the eye can distinguish up to approximately 20 different lighting intensities. This makes the act of "seeing a relative sense not an absolute sense" and a momentary sense, due to the inability of the eye to remember absolute brightness and colour (Volf, 2011). This is important to consider in relation to the complexities associated to designing with daylight quantitively. It is worth bearing in mind that this relational physiological attribute that humans possess can provide relational values, indicating an approach encouraging connections between otherwise dislocated lighting design information.

> *Current applications focus on dynamic artificial lighting, possibly triggered by commercial possibilities or incentives, but much less on how to bring daylight into buildings.*
>
> *(Solt et al., 2017), p.22.*

The optimal use of daylight in architecture for human health and well-being is a new challenge that goes beyond and may even contradict some of today's energy consumption standards. In particular, limitations imposed on window areas currently found in some energy standards are focused almost exclusively on technical data and aim to reduce the consumption of heating/cooling energy.

Recent lighting research has developed our awareness and understanding of the value of a window in an inhabited space. We now know that a window can provide much more than amenity (as was the guiding principle in the 1960s when recommendations for window sizes were introduced) but windows also offer health and well-being benefits through visual stimulus and the non-visual effects of daylight

[7] *Discomfort glare arises from any light source whose luminance is greater than the eye can adapt to, this can be instant or over a period of time.*

on the human body (Baker & Steemers, 2002), (Boyce, 2010) and (Burnett, 2015). This is a clear application of criteria that responds to one agenda, energy efficiency, but forgetting all the health benefits of a view out and access to daylight we have learned from lighting research. Any designer wishing to create a larger glazed window to wall ratio will be discouraged due to the "innovative solution" they will need to adopt.

Current Scottish government guidance adopts a singular attitude towards glazed apertures, viewing windows as heat sinks and subsequently window to wall ratios are now minimised to address this issue as can be noted from the excerpt below:

6.2.2 Areas of windows, doors and rooflights

Due to the carbon emissions Standard 6.1, there is no need for guidance on minimum or maximum area for windows, doors and rooflights in new dwellings. The use of a methodology for establishing compliance with Standard 6.1 provides an equitable approach to balancing the issues of heat loss versus solar gain and natural lighting versus artificial lighting.

In certain cases where there is a desire to have a large proportion of glass it may be difficult to demonstrate compliance with Standard 6.1. In such cases, innovative solutions will need to be considered.

Scottish Government - Building Standards technical handbook 2017: domestic buildings, Section 6 (Energy)[8]

These standards allow satisfactory solutions for most design tasks, but do not provide sufficient flexibility to encompass physiological, aesthetic, and cultural needs or special urban situations. Revised lighting standards now include metrics to quantify biological light exposure doses in some countries. This is all based on quantitative measures associated with scientific epistemologies. Scientific research provides us with empirical evidence that we are indeed, as Tregenza (2018) describes "bound in with daylight". However, it can be clearly seen that also for qualitative reasons, daylight should be complementary and synergistically incorporated into architectural designs so that time of day and the seasons can be seen and experienced within our living and working environments.

[8] *The Building Standards technical handbooks provide guidance on achieving the standards set in the Building (Scotland) Regulations 2004 and are available in two volumes, domestic buildings and non-domestic buildings.*

If this description is to be understood and applied appropriately to the architectural designed spaces, then those in the “Community of Practice” (Wenger, 1998) creating spaces for humans to inhabit cannot ignore these relationships and the resulting qualitative and quantitative design implications this implies.

Further to this brief summary of literature on quantitative approaches to daylighting, this thesis continues by exploring and defending a qualitative approach to daylighting. It seeks to outline an understanding of qualitative characteristics of daylight and challenges the intuitive nature of this epistemology for daylight.

2A.12 How can daylight be a contributer to architectural space?

> *Anyone who has written about light and lighting realizes the enormous challenge in trying to describe such an elusive and intangible commodity.*
>
> *Peters in (Millet, 1996) Foreword, pvii.*

Designing creatively with architectural space requires qualitative understanding of the atmosphere of spatial environments within a specific social and cultural context. However, this is difficult to achieve, and all the more apparently so when we try to define the complex nature of daylight and what it is to design with it successfully.

Daylight, as an intrinsic part of this atmosphere is therefore viewed as ephemeral, difficult to capture and assumed difficult to design with.

> *What do we mean when we speak of architectural quality? It is a question that I have little difficulty in answering. Quality in architecture . . . is to me when a building manages to move me. What on earth is it that moves me? How can I get it into my own work? . . . How do people design things with such a beautiful, natural presence, things that move me every single time. One word for it is Atmosphere.*
>
> *(Juhani Pallasmaa, Zumthor, Havik, Tielens, & Teerds, 2013), p. 1.*

Architectural theorist Mark Wigley in the 1998 issue of the architecture journal Daidalos, dedicated to the ‘construction’ of atmospheres, questioned why the notion of atmosphere lacks attention within the profession. He argued that the discussion of atmosphere in architecture entails, by definition, a certain ambiguity. After all, atmosphere is something personal, vague, ephemeral and difficult to capture in text or design, impossible to define or analyse. Atmosphere, Wigley says, is precisely that which evades analysis (Mark Wigley, 1998). He discouragingly suggests that although atmosphere can be understood to be the essence of architecture, it is not easily defined, let alone constructed or controlled. Mary Ann Steane (2011) highlights in, “The Architecture of Light” using natural lighting within architectural design is a “complex but ultimately rewarding endeavour”.

However, atmosphere, it can be argued, is “the very initial and immediate experience of space…a notion that addresses architectural quality” (Zumthor, 2000).

> *Illuminating a space makes life possible within it. The way in which a space is lit determines, to a large extent, its characteristics and quality.*
>
> *(Valero Ramos, 2015), p.1.*

Therefore, if a designer understands the quality of daylight they wish to create in a space do the characteristics and atmosphere not follow suit, corresponding to the particular quality of light? A review of theorists work in this area confirms that many would agree that although quality of daylight does affect the atmosphere of a space there are many other factors involved in its creation.

> *An atmospheric perception also involves judgements beyond the five Aristotelian senses, such as sensations of orientation, gravity, motion, duration, continuity, scale.*
>
> *(J. Pallasmaa, 2014), p. 231.*

Yet, if we examine these perceptive constructs closer we find that many of these are sensations informed by the behaviour of daylight in a space.

> *The control of light has aspects that are both functional … and expressive, the latter considerably predating the former. That*

is, long before studies were conducted on task performance, ocular fatigue, and seasonal affective disorder, light served in the manipulation of spatial effect.

(Malnar, 2004), p.250.

We can intuitively understand our orientation through the angle of the sun and shadow and the duration of these movements (motions). This too informs our understanding of gravity within the architectural space as we know the sun rarely comes from below (exemplified by artificial uplighters creating menacing, unnatural shadows) but the sun rises and sets from the horizon towards the upper dome of the sky (zenith) and back to varying degrees depending on latitude. Our interior spatial volumes, furniture and material serve to transmit sensations of scale as we understand the material properties and the behaviour of light interacting with them. If the designer possesses sufficient understanding of these daylighting relationships and can envision the lighting quality they wish to create in a space is this sufficient to achieve the atmosphere they aim to create?

A design solution, realised in this way is at best intuitively constructed. Very few architectural design projects are replicating spaces that have been previously built or experienced as most projects are unique in some way. They may be placed in a different orientation, support different architectural volumes or relationships of volumes, include new material finishes or a new combination of finishes or at the very least have a unique location. Worryingly, using an intuitive approach alone the prediction of the outcome of the lighting quality that will be achieved in the space has no empirical basis other than an intuitive understanding of the behaviour of the sun. Without quantitative analysis the designer has little guarantee that the design proposal will be appropriate and create within it the atmospheric condition they planned for.

Therefore, if daylight is accepted to be a contributor to the atmosphere of spatial design, it becomes necessary to assess how this can be defined and developed from a simplistic, intuitive rationale to an informed valuation according to the known behaviour of daylight. This approach currently diverges from the quantitative ontological perspective demanded of the lighting standards and metrics discussed previously. However, it is expected that through review of an alternative qualitative ontology for daylight, insights into connections between these two, seemingly opposing ontologies, may converge.

Hawkes (2008), an architect and award-winning academic and researcher proposes that the nature of architectural design requires an understanding of both realms, the quantitative and qualitative, the physical and virtual, the ultimate challenge being to understand the “unquantifiable aspects of architectural design” between the two. Millet, a professor of lighting who has written extensively on daylighting criticises the separation of the two apparent ontologies for light; qualitative and quantitative as “either solely for aesthetic purposes, or solely for providing visibility for tasks” (Millet, 1996), p2. It is therefore proposed that the difficulties in designing with daylight that this scenario creates is damaging to daylighting design outcomes in one of two ways: i) The design project will lack a holistic approach providing either a good quality of daylight aesthetically or be successful environmentally but rarely both, ii) The epistemology of the practitioners will evolve only within their chosen set of values and understandings of daylighting which is detrimental to future clients, building users and advancements in architectural design.

Approaches to daylighting design attributed to these two apparent paradigms is further discussed and demonstrated through proceeding sections of the thesis. These sections examine the rationale for the commonly understood, prescriptive definitions and ‘values’ attributed to the immeasurable “spiritual” (Plummer, 2009b), “thingness” of light (Holl, 2000) within spatial design and the qualitative aesthetics of daylight.

2A.13 How can we understand the immeasurability of daylight and what epistemologies align with this perspective?

> *I believe in an emotional architecture. It is very important for humankind that architecture should move by its beauty: if there are many equally valid technical solutions to a problem, the one which offers the user a message of beauty and emotion, that one is architecture.*
>
> *(Ambasz, 1976), p.8.*

We understand and appreciate that much of our response to architecture and light is associative, emotional and multi-sensorial (Zumthor, 2000), (Pallasmaa, 2013), (Millet, 1996) without the need for empirical evidence. Our primitive desire for light is explicated through our physical seeing and psychological needs.

This is often the forgotten benefit of daylight that we experience as building users. It is only when the element of daylight is missing that we start to question its value and long for the “spiritual” and “physical satisfaction” (Plummer, 2009b), p6. Daylight is known to provide within a space an atmosphere transcending beyond what is a necessity. In his seminal book, The Eyes of the Skin: Architecture and the Senses (1996), Juhani Pallasmaa states that: “In great architectural spaces, there is a constant, deep breathing of shadow and light; shadow inhales and illumination exhales light”, inviting immeasurable, phenomenological epistemologies in relation to embodied experiences of light within architectural space.

Poetics of Light by H. Plummer (1987), architectural professor and photographer, explores and describes daylighting techniques and how we can experience spaces as the lit space is revealed. Plummer’s research over many years has involved visiting architectural spaces, experiencing the spaces first hand and creating descriptive text of lit spaces for journals and books (Plummer, 2009a) and (Plummer, 2012). Most notably, in “Poetics of light” (1987), the reflexive nature of his spatial descriptions allows room for further creative interpretation. By providing a viewpoint of a space linked with images, any reader can negotiate and reflect on his writings and photographs in relation to their own understandings of the space. It is proposed that Plummer bases his photographic research and writings on daylight within the field of phenomenology, focussing primarily on the development of a poetic language to experientially describe lit spaces. Interviews highlight his continual struggle to describe the most, “immaterial aspects of architecture” and the human experience of being in a space touching, “perceptual”, psychological”, “emotional” and “spiritual” realms. Lighting designer *Alberto Campo Baeza aligns with this perspective of the effect of daylight in a space when he discusses* light as having:

> *The capacity of endowing that space with such quality that people are deeply moved by it.*
>
> *Alberto Campo Baeza, La idea construida in (Valero Ramos, 2015), p. 46.*

Plummer observes that this is a necessary exploration for anyone needing to gain insights into “aspects of light that lie beyond foot-candles and lumens” (Schielke, 2015). He proposes theories on architectural lighting design advocating that each designer “forms” an idea into a physical space by modulating the daylight into a space “consciously and unconsciously”.

Plummer has developed a way of seeing, or a way of presenting spaces to convey the specific ambience he had chosen to convey in his poetic descriptions of light in architecture. His pedagogical approach also demonstrates an epistemological perspective that advocates that in experiencing an architectural space. He suggests, “there is not a correct meaning”, but rather, alternative meanings “imposed by ourselves, rooted in personal experience” that affect our own distinctive understanding and appreciation of it. He allows us to see the architectural space through our own interpretations of his selected and intentionally composed architectural photographic studies in his books. It is Plummer’s photographic images and descriptive text that encourage us and give permission to delve into our own connections with daylight’s “miraculous capacity to bring things alive at a sensory level, and to create, before one’s very eyes, a sudden intensity of being” (Plummer, 1987). He demonstrates an epistemology that situates daylight as the generator of the spatial atmosphere, transcending necessity and the “limits of objective reality” (Plummer, 1987). Plummer discusses the increased intensity with which some architects during the past century have chosen to explore daylight within their buildings. It is clear that his epistemology of daylight aligns with those he portrays as “most sublime architects” with “finest contributions” (Plummer, 2009b), to the field of architectural design.

> *Rather than glamorizing form and gesture, these buildings are conceived, first and foremost, as domains of immaterial forces and energies, whose fluid events are linked to the sky but also demonstrate a way of seeing that is true to the world today. While not neglecting physical needs, which they tend to also satisfy superbly, these metaphysical works are striking in their elevation of light to a primary role in architectural expression…In each instance, daylight has been manipulated to give it a unique and palpable presence, and, more significantly, to transform objective reality, while constructing its place in a more fluid reality that people are empowered to creatively engage with.*
>
> *(Plummer, 2009b) p11.*

2A.14 How can an epistemology of daylight include both measurable immeasurable perspectives?

Holl, the architect, architectural writer and theorist reveals his philosophical approach to daylight and the values that underpin the design agendas he has developed for his architectural projects through descriptions of his own work in his published monographs. In his writing he advocates for the use of daylight in projects, as a haptic and emotional intervention in the creation of architectural atmosphere. He comments that without daylight the building user is living in deprivation.

> *As one can be condemned to eating only artificially flavoured foods, so one can imagine the spectre of artificially constituted surroundings imposing themselves in architecture today.*
>
> *(Holl, 2000), p.68.*

In an essay on Steven Holl's architectural works, theoretician Stanford Kwinter writes, "For Holl, architecture is the science of experience…Light is not itself the plenum of matter, but rather what reveals and conveys it (architecture), like water in the paper into which pigment is placed" (Safont-Tria, 2012). In the Museum of the City he designed for Cassino, Italy, Holl describes his design process as considering each exhibition area as beginning with a "neutral space individuated through its specific quality of light". This can, in turn be "played" with "bodily movement" (Holl, 2000), p114. Holl's understanding of daylight's contribution to the formation of space relies heavily on physical interaction and embodiment. He describes the "thingness" of light as interwoven with the built fabric of the building and as a relational phenomenon:

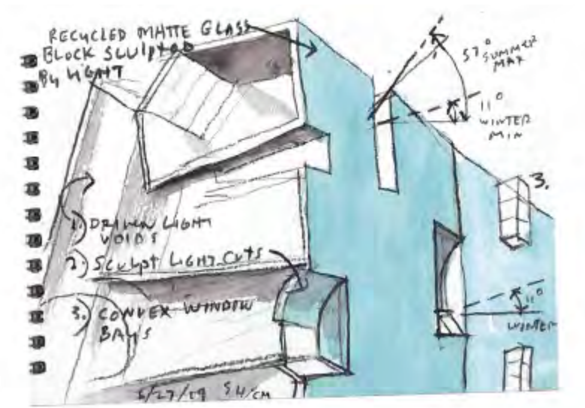
> *The twin entity (close, entwined, necessary relationship) of shadow and light allows us to read and understand the range of shadows (scalable self-defined) – from the pure umbra of total shadow to the penumbra of extended sources of light, creating the reality in which we live. There is a thingness to light that one cannot form with one's hands. Light is not verbal; we need images, we need spaces.*
>
> *(Holl, 2000), p. 114.*

Holl's writings clarify that he sees daylight, not as an individual element in a space but as one of many bound up in the space.

A complex interlocking of time, light, material and detail creates the cinematic whole wherein we can no longer distinguish individual elements.

(Holl, 2000) p.65.

However, Holl does not only align with the embodiment of daylight in an architectural space, conforming to a straightforward phenomenological stance. He is aware of the importance of daylight as a measured element. He describes the ideas in his book “Parallax”(2000) as affirming “a spirit in architecture and discoveries in science and perception” and ”tries to explore the relation of one to another”. His drawings indicate an awareness of sun positioning and the behaviour of daylight through his published sketches of his architectural projects.



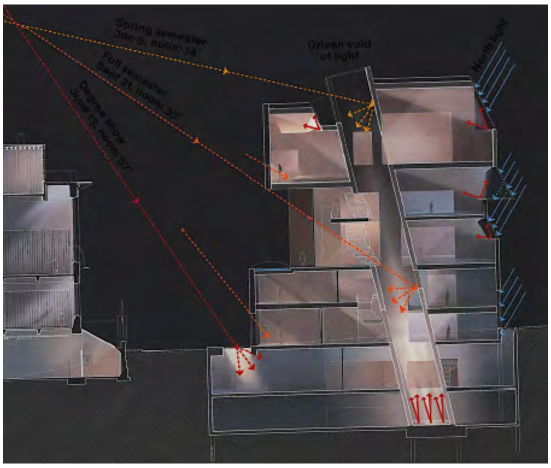


Figure 4 Glasgow School of Art Drawings (Holl, 2000)

This alludes to his understanding of both the science of daylight and the relational context within which it is possible to design. He also indicates this holistic perspective when discussing spatial volume as he suggests all the senses are involved in the space, giving a “quality bound up in perception” (Holl, 2000),p31.

This understanding of our emotional and physical connection to daylight is difficult to define. We can however find a rationale for it based on the physiological and psychological studies as discussed in the previous chapter. Findings regarding our relational vision, our need for light and equally, our need for dark, provides some clarity and empirical evidence to substantiate our embodied relationship to daylight.

Rasmussen in his book on experiencing architecture suggests that quantitative measures identifying “variations in the daylight” have little relevance to our experience of a space and “can be ignored, for though they can be measured with the help of instruments, we ourselves are hardly aware of them” (Rasmussen, 1964) p187. This perspective suggests that quantitative daylighting measures are of little benefit to the designer within the design process. Conversely, when designing with daylight, many designers are aware that using experience and intuition is also not the only way in which daylight can be designed. Reliance on these subjective techniques alone can result in a project that falls short of its design aspirations, particularly if the designer does not yet hold this “experience” consciously.

This view seems to be shared by Holl in some respects as he discusses the “mysterious” nature of science but through his drawings and textual outputs he alludes to an awareness of a scientific basis for lighting design that can aid designers in their perceptive awareness and intuitive design decisions.

> *Science remains essentially mysterious, yet our daily scientific and phenomenal experiences shape our lives; experience sets a new frame from which we interpret what we perceive.*
>
> *(Holl, 2000), p.14.*

In summary, it can be demonstrated that both Holl and Zumthor, as spatial designers, align with epistemologies for daylight that overlap between the measurable and the immeasurable. These designers prioritise the qualitative, embodied notions within the spaces they design, yet, they also allow for an informed technical appreciation (quantitative) of how this can be achieved. Whether through drawing (Holl) or experience of built past projects (Zumthor), this methodology strikes a balance providing a holistic framework within which previous projects can inform, new projects can develop and future projects can settle. By inhabiting broader ontologies for daylight, the spatial designs they propose form a conceptual core that can evolve as necessary for each project in turn. It is intriguing to note that those designers famed for their phenomenological approach, with qualitative experience at the forefront of any design, are the designers that succeed in addressing both qualitative and quantitative ontologies for daylight successfully through their informed technical design knowledge.

With this clarified epistemological stance as an achievable goal it is important to consider more how this can be reached as a spatial designer. This therefore necessitates analysis of the pedagogical approaches that may instill this developed understanding of daylight.

The next section questions what currently exists in the domain of lighting design through analysis of published pedagogical methodologies. It then highlights literature found in relation to this grander idea of converging ontologies, including examples of this theoretical construct from out with the domain of spatial design.

Chapter 2B Pedagogical Review

2B.1 Design Pedagogy – an introduction to the basis of pedagogical approaches for daylighting through spatial design

There is no single meaning of the term "pedagogy", and design pedagogy in a similar way has no single distinct meaning due to the many cultures and practices within design. For the purposes of this thesis, pedagogy refers to repeated patterns or characteristics of teaching and learning practices that shape the interactions between teacher(s), learner(s) and the design. In this context it therefore implies the strategies or styles of instruction. The methodologies of teaching and learning practices form this 'pedagogical approach', with the use of didactic methods as teaching tools to define disciplinary concepts. This idea of pedagogy is summarised below:

> *If we believe that knowledge consists of learning about the real world out there, then we endeavo[u]r first and foremost to understand that world, organize it in the most rational way possible, and, as teachers, present it to the learner. This view may still engage us in providing the learner with activities, with hands-on learning, with opportunities to experiment and manipulate the objects of the world, but the intention is always to make clear to the learner the structure of the world independent of the learner.*
>
> *(Hein, 1991)*

The approach outlined above is important to consider as this chapter reviews pedagogy within spatial design. It assists in defining current pedagogical epistemologies and how design teaching demands a somewhat different approach. Hein's (1991) last phrase (above) refers to the understanding the educator has of a principle or concept and the passing on of *their own interpretation* of it to the learner.

This methodology, although a common approach within many current teaching practices, and one that many educators would accept, does not sit easily with design disciplines. The field of design requires learners to develop a view of the world through their own interpretation of it, engaging with it, 'experientially', allowing the formation of their own epistemological perspectives.

In the domains of design (including spatial design) Constructivist pedagogy, known for its ‘experiential’ approach is therefore commonly used. Although superficially this pedagogical perspective looks and feels very like the approach Hein has described above, the way in which a learner is expected to create their own knowledge within design disciplines is often very different.

Constructivism is an educational theory that aligns with active learning methods; hands-on, activity-based teaching and learning, during which the learner can develop and evolve their own frames of thought (Keengwe & Onchwari, 2011). Underpinning this approach, constructivism is based on Dewey’s principles of active learning and Piaget's learning theory; learners have to construct their own knowledge, individually, and collectively through new connections and social constructs. Constructivism proposes that every learner has an ontological toolkit of conceptions and skills with which he or she must “construct knowledge” (Keengwe & Onchwari, 2011) to solve problems presented by experiencing the physical and social environment and justify that knowledge through their learning (epistemological). This theoretical understanding therefore substantiates that physical, active learning principles alone are not sufficient for this learning methodology. It is understood that the mind must be engaged in reflection to permit this learning to happen (Hein, 1991).

Constructivism seeks to create studio environments, “with goals that focus on individual students developing deep understandings in the subject matter of interest and habits of mind that aid future learning” (Richardson, 2003, p. 1627). By examining example case study pedagogical approaches to daylighting within spatial design, this research study aims to expose the methodologies that underpin and organise current learning methods; and discover methods of aligning then evolving design practices through changing epistemological perspectives.

> *Design studies pedagogy is a curious part of this educational milieu, in that it often draws from each of the varied pedagogical approaches simultaneously. Design studies pedagogy relies on the scientific method of observation, hypothesis and evaluation, while simultaneously exploring visual and spatial hypothesis through constructing environments and making objects.*
>
> *(Kaiser & Ogoli, 2016), p197.*

The challenges of design pedagogy expressed by Kaiser can be seen in the variety of teaching models we can observe in current design courses available to the prospective design student, (Kaglar & Uludag, 2004) (Lisa Domenica, Christine, Ute, Loukas Nickolas, & Malcolm, 2013), (van Dooren, van Merriënboer, Boshuizen, van Dorst, & Asselbergs, 2018) (Aşkın Gülsüm, 2018).

> *While the practice of design professions has changed significantly and continues to change, architectural and urban design education has been slow to react to these changes at best or resists change or adaptation at worst.*
>
> *(Salama, 2015), p.31.*

The development from modernism to post-modernism has gradually been reflected in a changing approach to design. The modernist movement has encouraged the "perception of the designer as omnipotent artist and creator, making decisions based primarily on aesthetic, financial, theoretical, and political concerns" (Milburn & Brown, 2003), p47. These emergent issues have placed greater emphasis on sustainability, environmental responsiveness and human health (Milburn & Brown, 2003), p47. Within the contemporary educational paradigm that highlights attitudes, societal demands (in addition to knowledge and skills), a change in design education is ever imminent and necessary (Steinø & Özkar, 2012), p8. The skills of the contemporary designer need to fit within this paradigm that demands clarity of reasoning and action, based on these challenging societal demands and values.

Spatial design practice evolving around a project, has within its processes of project brief and its built realisation, the capacity for action and reasoning to interact. It is within these processes that the capacity to reflect on actions that permits the designer to create and justify his/her own practices Heitor and Bastos in (Steinø & Özkar, 2012) and (Holder, 2014). The spatial designer's training, as well as the design concepts developed and discarded over time, play an important role in the formation of the individual's design identity Musgrave (1984) in (Steinø & Özkar, 2012). As discussed previously through my own observations, it is expected that the epistemological perspectives the designer holds therefore have some basis in the pedagogies and teaching practices they have been exposed to. In architectural design pedagogy studio teaching is often located at the physical and theoretical core of teaching practice (Stephens & Fixsen, 2017), (Salama, 2015). Studying the pedagogical approach in a studio environment therefore provides a potentially rich field of theoretical and practical design data revealing design processes and results of pedagogical approaches.

In spatial design education, using a Constructivist approach, learning within a design studio is understood to be a discovery of “seeing design as a process of creativity within a contextual framework” (Kaglar & Uludag, 2004). However, Brown et al. (1989) argue through a constructivist lens, with a note of caution. The learning of a discipline in educational contexts is often distinct from the “authentic activity performed by practitioners in their everyday work, isolated from the ordinary practices of the culture” (J. Brown et al., 1989), p. Instead, they propose that pedagogical approaches should “enculturate students into authentic practices through activity and social interaction” (J. Brown et al., 1989). The studio as a setting for this research study and a design brief for the spatial design student to respond to therefore goes some way to acknowledging Brown’s et al. theory, through its close relationship to professional design studios and the design practices that take part within it through developing a unique CoP.

Studio sessions such as workshops or tutorials are commonly based around a project brief. This brief also serves as a powerful tool in the development of epistemological foundations for the design student. It advocates for exploration of selected contemporary design issues through the design process as prescribed within the boundaries of the brief. Whilst responding to a design brief in the design studio environment, behaviours can be seen to emerge that demonstrate where and what the designer sees as important and at the forefront of their thoughts. These behaviours are understood to be a manifestation of an integral consciousness of the student and the design educator, demonstrating the development and “adoption of values” (Boud, Cohen, Walker, & Society for Research into Higher, 1993), such as design aspirations, cooperation and reflection on design as cornerstones of the integrative design studio. This suggests that although design studio allows for learning by doing it is not simply the practical making that is the learning process but the design thinking also.

> *The design studio is both a process and a place. As a place,*
> *it is where most of the work goes on.*
>
> *Rachel Sara in (Lyon, 2011).*

The design studio invites explorations through varied processes with the setting supporting collaboration and developing design thinking. Design students are expected to learn about the process of design through their engagement with the project whilst responding to the project brief. Studio-based learning is characterized by: the identification of a problem (in many situations outlined in a project brief), followed by a period of design development augmented by desk critiques and presentations (Lackney, 1999). The spatial design studio is an example of the context within which a design student might engage with a design project brief that includes daylighting design. However, a clear challenge appears as we examine the role daylight plays within the field of architectural pedagogy where design studio pedagogy is highly valued and assumed.

The next section of the thesis therefore outlines and discusses how the teaching of daylighting is placed within spatial design contexts. It seeks to ask how daylighting can be taught as an integrated part of this valued spatial design studio pedagogy? Further, if this approach is considered appropriate, how can current epistemological approaches to spatial design pedagogy evolve to allow this integrated methodology to succeed?

2B.2 What place does daylighting hold within spatial design education?

In the UK the Oxford Conference of 1958 was seen as a dramatic turning point for the inclusion of ‘technical’ skills, such as daylighting, within architectural education. Traditionally, lighting played an important part in building design implicitly, even if not explicitly taught. Until the post-war period, prediction of daylight in interiors was mostly associated with law rather than comfort (Addleson, 1972), p88. Please refer to section Chapter 2a.6 and 2a.7 for further information on this aspect.

Lighting was at first taught with emphasis on the numerical values, regarded traditionally as an advanced subject, as “part of building services”, but further to this seminal architecture education conference some schools made vigorous attempts to bridge the “quality-quantity gap” (Addleson, 1972), p88. A new, greater acceptance of “science within the design process” provided opportunities for consciously experiencing the visual environment in a technical lab environment, previously positioned to provide only an introduction to lighting quantities. This also initiated a gradual development of research into the value of daylight for building users beyond task lighting requirements. Although rarely fully integrated into design studio settings (and therefore the architectural design project/project brief), these advances were beginning to define a new epistemology for lighting. Daylighting, as a subject, now had some value apportioned to it within spatial design processes and pedagogy.

As the field of building science grew in the UK from the 1960s onwards, daylighting "science" (Addleson, 1972), (Salama, 2015) was widely taught in schools of architecture. Daylighting study was primarily through lecture courses and Addleston (1972) notes that these lectures were often given by "building scientists" who "often lacked expertise". Significantly, daylighting, as a subject was separated from design studio and was lecture based. Students were then expected to "apply these known constructs to a space or form, thus advancing the notion that light is an additive to design work" (J. Theodorson, 2006) in (Gustina, 2011). Further, these lectures were "grounded in teacher-centred, deductive methods (with) learning and assessment based on recognition, recall and simple application", (Judy Theodorson, 2012), p596.

Teaching daylighting design within the traditional lecture theatre provided a physical space for what educationalists now call passive or teacher-centred approaches, where students were presented by the instructor/lecturer the relevant facts, figures and calculations. This teaching format is suited to larger numbers of participants in one sitting, providing a point for the giving of information. However, the methodology behind this technique has come under much criticism within contemporary pedagogy as it creates a situation that encourages the participant to take a very passive role in their learning. The use of a range of pedagogies is applauded by contemporary educational theorists who discourage a lecture-based approach in favour of innovative pedagogical formats in design that promote deeper contextual exploration of the subject (Peterson, Dumont, Lafuente, & Law, 2018). The Constructivist ideas of Papert are now prevalent, promoting experience led methodologies "and a major shift of emphasis away from teaching a discipline as a body of knowledge towards an exclusive emphasis on the experience of the processes and procedures of the discipline" (Hodson, 1988).

The physical arrangement of the lecture space, rather than the design studio, prevents continual feedback or discussions, “making it challenging to instil deep understanding” (Baumbach and Phillips IDEC) and, in the field of design specifically, encourage questioning and reflective design observations. Further methodologies for the teaching of daylight also embraced a scientific approach through lab experiments to measure light (Lewis, 2017), but rarely were relationships to architectural space or the spatial design studio ever made.

These methodologies for learning about daylight are now less common. Although in some architecture and design schools lecture series are still prevalent, daylighting has become a topic that is now regarded as:

- the study of light (developing architectural aesthetic) and is taught and guided by studio tutors
- an ‘architectural technology’ within an environmental epistemology for design that warrants analysis in teaching ‘labs’ through digital technologies modelling architectural space

These differing roles for daylighting design within spatial design pedagogy are defined by the design department, school’s curriculum or course leader and may align with either one or other of these roles, occasionally both. This can be explained by the broad application of lighting within spatial design and the environmental design disciplines. Therefore, it is assumed that the diversity of the ontological perspectives of those who teach daylighting and their over-arching epistemology of design (shaped by their CoP) will influence the pedagogies and methods they use in their teaching practice (Ching, 1987, p. 126). A design educator’s epistemic perspective is revealed through their pedagogical practice, influenced by the “material ideological apparatus” they engage with (Melles, 2013), p. 2.

Although the epistemologies for daylighting apparent within these current approaches are clearly diverse, the ontological perspectives presented as a whole curriculum allow for understanding of both quantitative and qualitative characteristics of daylight if both pedagogies are indeed included. It is not however evident if a balanced approach has been taken towards these different ontological perspectives for teaching daylight. The difficulty for any student experiencing this type of curriculum is associating these diverse ontological perspectives for daylight to form relationships between them. Without these associations, the development of a balanced epistemology for daylighting design that recognises understanding of both qualitative (aesthetic) and quantitative roles becomes difficult.

Aligning with these theories, Theodorson, an eminent lighting and interior design educator, comments that she has observed design students tend to have “little retrievable information around light’s physical behavio[u]rs, impacts, qualities, or intensities” (J Theodorson, 2011). She suggests that this challenging situation is, “rooted in the lack of activities and guidance that build literacy and recall around light” (J Theodorson, 2011). These findings allude to problems with both the setting for learning and the lack of physical experimentation (or even the range of activities) possible in the lecture theatre format limiting cognitive opportunities (Coorey, 2016), (J. Williams, Stables, & Williams, 2017). It is proposed that these issues are also related to the pedagogical approaches to learning in spatial design contexts; the lack of teaching of joined up thinking regarding daylighting ontologies and exposure to the contextual relationships of daylight and architectural space.

2B.3 Defining current pedagogical approaches to daylighting design

> *Design education is distinctive in that it requires knowledge assimilation from a variety of perspectives with application to complex and unique design problems. It thus follows that students will benefit from an integrative pedagogical approach to teaching light; one that provides opportunities for the student to develop personal and disciplinary constructs.*
>
> *(J Theodorson, 2011), p114.*

We understand that in design the unique problems that designers work with demand knowledge content from many sources. It is the designer that needs to understand the assimilation of this content through an understanding of relationships and priorities. For spatial design, the relationship between light and interior space is a mutually dependent and significant one. “Light renders space; without light, form, colo[u]r, texture, and scale are unrecognizable” (Beever & Blossom, 2009), p. 35. In return, space captures light receiving it, shaping it, bending it, hiding it. This suggests that in order for daylight to be fully understood and worked with holistically in an architectural interior it is vital that the various relational behaviours of daylight interacting with the surrounding context must also be understood. Unfortunately, there is evidence to suggest that this is not currently a typical approach to working with daylighting in architectural design educational contexts.

Lighting educators have highlighted that, “the intentional manipulation of light, both artificial and natural, is treated as an afterthought”, “oftentimes relegated to mere appliqué rather than an integral facet of a particular design solution” (Whitehead, 2009). These findings suggest a lack of holistic design intent and little priority of the relational characteristics of light to surrounding context. Beever and Blossom, interior design educators and linguistics specialists also warn that, “light is most often applied to an interior design solution as a functional additive rather than considered first as an essential design element” (Beever & Blossom, 2009), p. 35.

Intriguingly, we only need to look back over the historical use of daylighting in architectural projects in the UK in the last 50 years to present a rational for this. The strong affiliation to science and technology that daylight has had and increasingly has, reinforces ‘analysis’ of daylighting rather than the consideration at first concepts stage. Daylight is rarely now a generator of architectural space but rather, has become a system or service for the space that needs quantifying through analysis towards the end of a project. The methodologies and tools used for daylighting design encourage this quantitative ontology for daylight. As verification becomes a priority for the building construction industry, developing digital analysis methods provide “increasingly precise tools for assessing design” (Lawson, 2006), p71. With this mono-ontology for daylight based on a quantitative rationale, “This raises the question of how designers’, educators’, and students’ approaches to designing with light might be redefined to regard light as a significant contributor to spatial compositions” (Beever & Blossom, 2009), p35, aligning with qualitative ontologies for daylight.

Design educators have identified this as a gap in design education, forwarding a variety of proposals to better integrate the study of light into the overall curriculum. Millet and Loveland (1997) suggest that opportunities for learning “lighting design” (as opposed to “lighting science”) be offered in multiple learning venues throughout design education. Fontein (1997) and Poldma (2009) introduce methods of design inquiry in lighting technology courses. Brown (2004) emphasises the importance of studying the three dimensional aspects of light and space through design problems. Theodorson (2006), suggests that abstract light projects for the beginning design student will help foster an emotional and visual relationship with light. Stannard (1997) introduced an advanced design problem in his teaching that forces light to act as a generator of form and space. The common thread in these approaches is the notion that expanded perspectives around light emerge by engaging nonlinear methods that "criss-cross" (Judy Theodorson, 2012) the realms of design and technology.

Many difficulties are therefore evident in the teaching of daylighting within architectural contexts. This research consequently aims to identify pedagogical methodologies that can be used appropriately in this specific context and can, in turn, contribute to pedagogical understanding in other design related areas. In order to recognise appropriate pedagogic methodologies, the following sections of the chapter aim to critically describe and explain other work in the subject-area. This review therefore includes current pedagogical practices, methodologies, pedagogical issues and particular demands of daylighting design within architecture.

This next section of the chapter introduces contemporary daylighting pedagogy through examining the ontologies proposed as a set of case studies and the methods used to align with the approach of each. This review of current pedagogical methods and approaches in architectural design/design courses has been taken from recent and seminal published papers and lighting text books. Example case studies have been included that can be described as demonstrating a pedagogical approach that aspires to new thinking or innovative or alternative methodologies.

For the analysis of each case study it was chosen to highlight the 'value' attributed to qualitative or quantitative aspects of each pedagogical approach. These findings seek to appropriate the study research questions and guide further investigation of appropriate methodologies and methods of daylighting pedagogy to ensure their cogency in both educational and future professional design contexts. The final section of this chapter provides a summary of insights from the current discourse on daylighting pedagogy from within and around the field.

2B.4 Defining Ontologies for Daylight Within Design Pedagogy

It is proposed that the design knowledge a design academic has and, in particular, the values they assign to it through their epistemological perspectives, can be analysed through their own pedagogical and ontological approaches. When investigating and collating a review of published pedagogical content for the teaching of daylighting to include in this research, it was found that there were a very limted number of resources. A broader range of case study publications were available from the larger field of 'lighting' design.

However, lighting design it seemed, viewed from a pedagogical perspective, resided in either the domain of continuing professional development for professionals (CPD, mostly artificial lighting, and often provided by lighting manufacturers) or the textbook (to align with lectures within a course often with a broader theme such as environmental design or architectural rendering). Although I know from experience lighting specific courses exist, and are increasing in number worldwide, there is little published work on pedagogical approaches used within these courses to review.

Therefore, the sources chosen for this review were selected from a limited but diverse range of 'case studies' of pedagogical relevance i.e. they consisted of educator's manifestos and ocassionally findings, from working with groups of design students on lighting courses or projects. Few of these publications provided sample outputs and less still any measurable results, but the majority described the process and methdology underpinning the course.

Therefore, this study collates a selection of case studies to identify the broad range of ontological and methdological approaches that have been and are still used within the field of lighting design. When examining each publication, I decided to strategically first identify the design academic's ontology for lighting and propose what these might be and second, how this is revealed through the methdologies they describe. Some case studies, where possible, relate directly to daylighting pedagogy and others from the broader field of design are included to provide a richer response of approaches. The findings from these are outlined in the proceeding sections with my proposed definition of the educator's 'ontology' and 'methodology' listed below each case study title.

2B.4.1 Case Study 01

Ontology - "Light as Element of Design"
Methodology – Contextual "Observation", "Manipulation", "Reflection"

Gustina (2011) identifies light as being "without boundary", its specific properties creating complex relations to the contents of interior space. He affirms the need to address light as an "Element of Design" rather than a "technical phenomenon" and has designed a set of lighting exercises to familiarise students of design with this elemental design ontology. His pedagogical approach was designed for 'first year' ('freshman', USA) interior design students. He introduces the need for an understanding of the behaviour of light through the "specifics of how light is produced and directed".

Gustina's "Elements of Design" approach was developed further to texts defining 'design principles' within "Interior Design Illustrated" by Ching (2005) and the effect of light interacting with objects and materials as demonstrated in images within Stewart's book (2008) "Launching the Imagination". Ching's book (2005) provides a basis for Gustina's emphasis of light as "Element" and "Principle" of "3-Dimensional Design" based on the pedagogical approach discussed by Brown (2004). Additionally, these "principles" are understood to have been taught to his participating group of students within the interior design studio as interior "elements" in the semester prior to the start of the lighting course. The familiarity of these "elements" was therefore instrumental in the success of introducing new lighting concepts using a similar methodology.

Stewart	Ching & Binggeli
3-D Design Elements	
Line	Form
Plane	
Volume	Shape
Mass	
Space	
Texture	Texture
Light	Light
Color	Color
Time	--

3-D Design Principles	
Unity and Variety	Unity and Variety
--	Harmony
Balance	Balance
Scale	Scale
Proportion	Proportion
Emphasis	Emphasis
Repetition and Rhythm	Rhythm

Figure 5 - Gustina's "Comparison of Terms - 3-D Design Elements and Principles.

He identifies three key methodologies included within his studio exercises and these methodologies were defined as four separate exercises;

- “Shine the Light” – A lecture based on Ching’s principles and a study using photographic lights or daylight to test different lighting effects with a summary of findings as the final step.
- “Rendering Light” – employs a “demonstration of techniques” for rendering light and the creation of renderings to include light.
- “Basic Lighting Model” – review of artificial lighting types/effects, a trip to “view lighting installations” and the use of a white cube physical model to test an “abstract interior composition”.
- “Final Project” – a practitioner presents their work then students build a physical model, draw and present their own intentions for a “final project”.

Although Gustina comments that some of the exercises are derived from others including Brown (2004), Theodorson (2006) and Poldma (2009) his creation of a series and sequencing of exercises is unique and pulls from different skillsets and practices within the domain of spatial design.

Some of these exercises are unclear as to their exact methods contained within the published paper so are difficult to analyse fully. For example, we are not told how the students actually “rendered the light”. Was this rendering using a hand drawing approach? Further, when the students used a white cube model to test “lighting”, we are unclear if this was taken outside to allow for daylight testing or was it an artificial system they were employing? Questions arise when Gustina admits that, “data on the effectiveness of these exercises has not been compiled” (Gustina, 2011), p525. Yet, he suggests that faculty members have noticed increased discussions about lighting effects and the students were achieving a “fair quality level” (Gustina, 2011) in class.

His conclusion proposes that as students learn more of the technical aspects of lighting they will still be able to use and integrate this new knowledge with their understanding of light as an “element” if this methodology has previously been introduced. However, his paper doesn’t confirm how or when the situation for gaining further technical know-how is expected to arise.

This published design pedagogy is relevant for this study as it exposes clear methodologies for lighting design through individual elemental considerations within a larger integrated spatial design. These methodologies link closely to contemporary design curricula in many design disciplines through the proposition for a sequential process for design learning and integration of new knowledge with familiar approaches. For daylighting design specifically, some of the more “unsituated” exercises are less useful. It is unlikely that these abstract environments created to explore artificial lighting can inform daylighting knowledge or suggest appropriate daylighting design methods in any obvious way as daylight is “situated” and location specific.

2B.4.2 Case Study 02

Ontology - Daylight as "Primary Design Material"
Methodology - Non-contextual "design brief exploration" through given building function

Ruttkay et al (2007) created a series of workshops over two days with an aim to integrate daylight theory with practice through the use of card box models, learning the technical aspects of light through physical manipulation of light at a reduced though nonetheless useful scale. With an aim to improve students' prediction of the behaviour of daylight, the project avoided any initial observing techniques through lectures or seminars ("dictating paradigms or creating easy design recipes", p706), but instead addressed a brief, providing given functions for the box space. These lighting design workshops were described as having approached the use of daylight and shadow as "primary building design materials". The process and protocols were clearly directed and timed with the methods used outlined as follows:

1. Formulation of brief/function of space
2. Physical sketching of ideas
3. Experimental work with card box
4. Representation of the design
5. Evaluation seminar

This process clearly addresses the exploratory nature of the design process and considers familiar materials and methods for the student participants. The manipulation of a physical model was approached in a similar way to Gustina's workshops in East Carolina University in that participants cut into a box to control and direct the light entering the space. With Gustina's first exercises participants worked with abstract space and place then continued in the following semester to define a space function and setting. Ruttkay's workshops provided a less abstract setting with a defined function but it is not clear why a context was not selected?

The physical sketching of ideas used chiaroscuro representation techniques showing where the light was, rather than shadow where the light was not. This method ensured that the light in the space was considered and defined specifically through tonal contrast and modelling but sometimes to the detriment of the materiality of the space. With an emphasis on the lighting of the model space was materiality therefore considered less important? It is not clear from the published results of these workshops that any importance was given to consideration of an architectural space in a holistic way. Ruttkay et al identify the need to integrate lighting into the design process yet the methodology employed was not particularly clear in defending this idea. The interior designer or architect working on the design of the space would need to consider the other elemental parts and as such would work with the lighting alongside the volumetric characteristics and material properties and this was not clearly addressed.

2B.4.3 Case Study 03

Ontology – Light as a Biological Need
Methodology – Exploration of daylight strategies (variety of tools)

Dubois's (2006) paper seeks for an "integration of daylight quality in the design studio". This teaching method was developed for a Masters Level Design Studio in Laval University's School of Architecture for the study of "Indoor Climate" (Physical Ambiences). The teaching methods used were extensive and varied; from "studies of daylight strategies in great architectural projects, readings, development of a lighting scenario according to basic biological needs and light transitions, quantitative analyses based on simple performance indicators, scale of shadows and contrast pattern analysis" (Dubois, 2006). The complexity and the diverse ontologies covered is demonstrated in the variety of tools required for these tasks, listed as; physical models, manual calculations and graphical methods, spreadsheet programs, computer simulations and more.

Although the range of topics and tools must be applauded for the scope they permit in pedagogical practice, the difficulty in the organisation of these is evident. The course was based around a five-week lecture series and studio discussions. The initial lecture considered daylight in "great architectural projects" and students selected a project from a defined list to study. Participants were asked to "describe and characterise each room of the building's program in terms of the response to Lam's (1977), p20-21, "eight biological needs". This study highlights an ontology for daylight that values environment and is human-centred – it is highly analytical.

Participants then continued with validation using “simple quality indicators” (Dubois, 2006) and analysis techniques to consider Frandsen’s scale of shadow technique and Demer’s Contrast Pattern Analysis. These orthographic analysis methods, although seminal at the time are now understood to be technically demanding for the limited information produced.

Analysis of the chosen space then continued to include many more daylight quality indicators including DF, luminance data (ratios and absolute), illuminance data and direct sunlight patches. Participants were encouraged to “choose the tool which best satisfied their needs in terms of information and with which they felt more comfortable to work with” (Dubois, 2006).

The results included in the paper show varied findings including images of lighting renderings using digital software but also, more importantly, successfully demonstrate students’ conclusions from their analysis tasks as summarised lists. Several comments are very insightful, suggesting some techniques clearly led to learning, although without analysis of these methods carried out in the design studio/lab we are not clear as to which ones were most successful. All the descriptions are numeric or strategic in format and this indicates a clearly analytical, quantitative approach as predominant. However, for consideration and alignment with the subject of this research study, these methods, relating to the teaching of daylighting design specifically, were considered to be useful source and starting point.

2B.4.4 Case Study 04

Ontology – Light as generator and form giver
Methodology – The aesthetic symbiosis of space, light, and shadow.

Stannard’s (1998) series of design assignments progress from the “analytical” to the “investigative” to the “functional” in their foci. The first assignment involves the construction and examination of large-scale models of prototypical dramatically lit architectural spaces, including works designed by Jorn Utzon, Tadao Ando, Renzo Piano, Alvar Aalto, and Louis Kahn.

Due to the remote location of the University and the inability to visit several exemplary daylit buildings, the physical construction of case study spaces was recommended to give students an opportunity to simulate the "experience" of these spaces. The primary goal of this assignment was to physically demonstrate the importance of daylighting as a “dynamic and constantly changing force” (Stannard, 1998), in architectural design. The assignments offered the spatial design student an opportunity to explore the variety of architectural experiences daylight and its constant motion brings to a space.

In addition, when practical, Stannard advocates for the inclusion of a study trip to visit buildings and lighting design professionals. During the visits, participants examined both daylight and electric lighting conditions. In an effort to develop the exercise (started prior to this with the case study models) the participants were encouraged to measure illuminance levels to quantify the quality of light in the spaces. This discussion of real-time measurement on location is one of the first instances that this pedagogical approach has been demonstrated and published in any concrete way. This technique was also used by Reinhart (Reinhart, Rakha, & Weissman, 2014) to assess the daylighting of a real space, although the approach in Stannard’s group was to ensure the integration of this information in a holistic way, rather than test students’ comprehension and ‘feel’ for the numbers in relation to daylighting.

Following the prototype investigations, students were asked to design an architectural "timepiece" in order to understand and to capture the power of the sun as a dynamic light source. This assignment asked participants to “ponder this general lack of connection to the cosmos and to design a building form that refocuses our attention on the sun's movement” (Stannard, 1998), p. 679. The sun was to be the ‘generator’ of the design idea.

To reinforce the idea that the dramatic use of light can be applied to a "functional" space, an existing space was used as a basis for the final exercise. Applying their accumulated knowledge, this exercise challenged participants to transform an existing structure using daylight *and* artificial light as the primary form giver to meet some given programmatic parameters. This given design problem further highlighted the functional requirements of light for specific tasks, the influence of different light types on perception, and the effect of episodic manipulation of high and low intensity light.

For the “analytical” and “investigative” tasks Stannard chose to invite participants to make physical models as he found they were not only essential for analysing lighting effects, but this method promoted a highly investigative approach toward spatial manipulation in the studio. As the interior surfaces were modelled appropriately for texture and colour as accurately as possible, working with large, scaled models focussed the participants' attention on the importance of materiality and detail in addition to light manipulation.

Handheld light meters were used for numeric analysis. This quantitative analysis was considered important for the more functional exercise as a method toward creating simultaneously usable and dramatically lit spaces.

It can therefore be seen that Stannard’s implementation of real case studies was highly practical and critically, his methods promoted techniques that allowed an interesting and dynamic comparison of the “situated and non-situated environment”. His methodology provided a clear balance between quantitative and qualitative analysis and ambitiously promoted daylighting to be the generator of the spatial design.

2B.4.5 Case Study 05

Ontology – Multiple Dimensions of Light
(Aesthetic, technological, functional)
Methodology – Cognitive Scaffolding Mediates Light as:
“Composition”, “Experience”, “Substance” and “Commodity”

Theodorson, architect and assistant professor of interior design at Washington State University proposes a challenging methodology for the teaching of daylighting (2012). Her ambition to criss-cross the “multiple dimensions of light”, supports exploration of the complex daylighting scenarios architectural design demands. Her aim is to utilise “markedly different” pedagogical approaches to those used in introductory courses to provide this scaffolding for an “intermediate stage of knowledge” (Judy Theodorson, 2012), p.596. She discusses light as having inherent overlapping of knowledge domains notably: “aesthetic”, “technological” and “functional”.

The first dimension, Light as Composition, focuses on the two-dimensional aesthetic and compositional potential of light. Similarly, to Gustina, Theodorson bases her methodology on Ching (1979):

- Light as a primary element (point, line, plane, volume)
- Light as a visual ordering principle (rhythm, repetition, patterning hierarchy, symmetry, transformation)
- Light as contributing to spatial organization (centralized, linear, radial, grid, clustered)
- Light as a modifier of space and form (expansion, contraction, privacy, directionality, temporality, performance, animation)

"Light as Composition" builds on the familiarity of basic design concepts whilst introducing light as a "primary visual media in the designed environment" (Judy Theodorson, 2012) Using model explorations and photography for iterative abstract experimentation, Theodorson sought to build skills in observation and encourage reflection.

"Light as Experience" focusses on "three-dimensional environments, emphasising atmospheric impacts on the human psyche" (J Theodorson, 2011). Intriguingly she emphasises literature sources for the discovery of metaphorical light, one of the first occasions this technique has been employed and published. Drawing, model making and photography are used to challenge the designer to shape their own understanding of lighting ambience. The published documentation does not confirm if any real spaces were visited as part of this experience.

"Light as Substance" defines light through physical ontologies and empirical data; colour, intensity, directionality, movement and heat. Didactics include exploration of building apertures through observation and experimentation.

Finally, "Light as Commodity" serves to highlight the "complex integration of natural light with architectural, interior and functional needs. Built scale models are used to test these aspects and "the nuanced impact of design decisions" (Judy Theodorson, 2012).

Although Theordorson's study considers the wider field of lighting design the publication provides persuasive discussion of methodologies, some of which are appropriate for daylighting design. Little empirical data of the success of the methods is included in the published paper, or specific details of the methods used to achieve the outputs, her work nonetheless proposes advancement in pedagogical approach, promoting multi-dimensional ontologies for light. It suggests a set of methodologies that are distinctive and yet independent of each other.

Pedagogical techniques are sequential or stand-alone exercises, however there is no clarity in the published paper as to how the “criss-crossing” (Judy Theodorson, 2012) methodology was addressed in the studio sessions. Although this approach allows for flexibility in the application of the pedagogical approaches, it is less easy to understand how this may fit with familiar design processes.

In summary, this paper discusses methodologies for the larger domain of architectural lighting that can be attempted, in parts, for daylighting. The methods of how this can be achieved are however left ambiguous, leaving it to the reader to decide how these ambitions for lighting can be addressed through their own didactic methods.

2B.4.6 Case Study 06

Ontology – Light as sustainable, raw material that can be measured and optimised (quantified)
Methodology – Sustainable practices - analytical

Andersen and Paule created a course for Masters level architecture students, (Espace & Lumière: Unité d'Enseignement M | Space & Light)(2011), aiming to improve students’ ability to see, to plan and to design light in architecture. Its purpose was to consider “light as a resource, a raw material”, and to understand how it can be utilised to “emphasise architectural concepts” (Andersen & Paule, 2011). The students were asked to adopt a sustainable approach focussing on analytical comfort and energy concerns. The following topics are addressed:

- daylighting principles and associated challenges
- visual comfort requirements
- artificial lighting strategies
- design and testing of a combined lighting project

The pedagogical approach was defined as a sequential process:

- Problem: visual and luminous requirements for each assignment
- Preliminary draft: determination of the lighting

- Sizing and verification: realisation of the lighting project

The students had the opportunity to use DIAL and Lightsolve software (for daylighting) and Relux (for artificial lighting) to quantify their lighting proposals and verify day and night scenarios. Lightsolve started at MIT in 2006 under the leadership of Professor Marilyne Andersen, and developed further at EPFL within the framework of her new research group, the Interdisciplinary Laboratory of Performance-Integrated Design (LIPID) within the Institute of Architecture at ENAC. Lightsolve uses CBDM to provide daylight performance over the whole year. Notably it, "produces a year-representative series of renderings that can be combined with a goal-based visualization of annual performance for illumination (based on desired illuminance ranges), glare (based on desired glare tolerances) and solar gains impact (based on probable heating versus cooling needs)" at an early point in the design process. The software takes a SketchUp 3-dimensional model and it performs a representative group of radiosity simulations, producing visual outputs.

Andersen and Paule comment that, "The students formulated hypotheses of solutions specific to their project, then tested and optimized to achieve specific performance objectives for their projects, taking into account in particular: the values of illuminance, luminance, daylight factor, autonomy in natural lighting, and the power installed" (Andersen & Paule, 2011).

The "criteria" that Anderson and Paule discuss needs further clarification to understand what domain specific knowledge for daylighting is understood to be. The case studies are further examined in Chapter 4 to inform a set of "threshold concepts" (Cousin, 2006) for this research investigation.

The paper does not include any analysis of the success of this method, using either software but does include the student outputs for the reader to review. Clearly analysis of results has taken place with discussions exploring illuminance values (thresholds), sunlight penetration angles and glare analysis. This appears very successful as analysis of the results is evident and the student discussions are informed by technical knowledge. What is less clear is where design iteration has taken place, although some student projects mention sunshades put in place to allow respite from glare.

Additionally, some projects demonstrate visually testing of card physical models which is interesting to see as this module outwardly seemed to encourage use of virtual environment tools in the briefing documents. On the whole, the teaching approach used in this study provides evidence that the software used provided the students with outputs appropriate to discuss, and in some instances, revise the design in relation to lighting and task requirements. There is less discussion of colour, materiality and texture within the design spaces. However, it clarifies that pedagogical approaches for daylighting design using virtual environments can be beneficial, particularly for Masters level students with the time and motivation to specialise in this area of design with lighting as a priority.

2B.4.7 Case Study 07

Ontology – Light as generator of "dynamic and mutable atmospheres"
Methodology – Sunpath represented technically (accurately set up and qualitatively evaluated)

Published as a book in time for PLDC (Professional Lighting Design Conference) 2015, Traverso, an architect, daylighting practitioner and educator provides introductory pages outlining his ontological perspective, discussing daylight as a generator of his own design work. He also includes a set of student responses to a series of workshops held through the University of Florida at the Vicenza Institute of Architecture (UF) between 2011-2015 that focussed on daylighting and, specifically, sun path. These studies used artificial lights with physical scaled models to mimic the position of the sun and its effect on interior spaces. The artificial lights, located in accurate positions (or as accurate as possible locations using the equipment available) were used to demonstrate sunlight's atmospheric effects in the physical, scaled models.

When viewing the exhibition of this work and the series of models displayed, the atmospheric effects were notable. As the lighting position changed (lights in different azimuth and altitude locations were turned on and off), the models demonstrated the 'mutable' effects of sunlight into the coloured and/or textured interior spaces that had been manipulated by the students' creative responses, with the floors, walls and ceilings sculpted, layered and carved into.

This project was clearly interior focussed. Many models included scaled figures and this perhaps allowed the atmosphere to be translated more successfully as those viewing the models could imagine engagement with the space. However, it was evident that the “deliberately abstract” (Traverso, 2015) model, with no function, had a specifically exploratory pedagogical approach. Although the models had a location and orientation (the diagrams in the book demonstrated this) allowing unlimited design scope, they did not conform to the difficulties of an “authentic” or ”situated” (J. Brown et al., 1989) context, where the aesthetic of the exterior of the building, the interior function and occupants task requirements cannot be ignored. It was also unclear if the experimental set-up was always an artificial one or if the models were taken outdoors and limitations in the use of this methodology must be noted here. However, this pedagogical approach clearly had its benefits. It invited student participants to engage with an experiential introduction to working with daylight (an enjoyable, encouraging task), but it also allowed for the full possibilities of daylight as a design material to be explored with very little limitation.

2B.5 Summary of Pedagogical Approaches

It is widely documented that design students often display difficulties in making connections between the design challenges they are tackling and the associated underlying scientific concepts and processes (Lawson, 2006; Mentzer, 2014; Salama, 2015).

All of the pedagogical case studies outlined demonstrate that it is possible to rise to the challenge of helping students make these important connections. Each case study handled this in a different way. Patterns emerged from each of the studies revealing that in every case the ontologies informing the pedagogical approach were different, such as “light as biological need” or “light as a design generator” yet the skills they wished participants to have and the concepts they wished them to explore had many overlaps and were often very similar; understanding of the behaviour of light through experiential discovery and analytical techniques.

It was also clear that most instructors did not necessarily align with the one ontological perspective I proposed but that they were understood to overlap with other approaches and agendas. An example of this can be seen in the case study outlined by Theodorson. Although the project was described as revealing the “Multiple

Dimensions of Light" this approach was also demonstrated as touching upon light as a generator of design ideas through light's role as "primary visual media in the designed environment"(Judy Theodorson, 2012).

All of the case studies aligned to some degree with Constructivist pedagogy:

> *[C]reation of classroom environments, with goals that focus on individual students developing deep understandings in the subject matter of interest and habits of mind that aid future learning.*
>
> *(Richardson, 2003), p.1627.*

Constructivist pedagogy aspires to achieve development of learning through "experience" to encourage "deep understandings" (Richardson, 2011). Brown, Collins and Duguid (1989), suggest this experience is approached in relation to the "situatedness" of the context within which the experience happens. It was therefore possible to review the set of selected case studies with this in mind, by considering the contexts the learner was presented with or immersed within "experientially" as they carried out the tasks set. Some pedagogical approaches emphasised learning from real experiences such as "situated" field trips, where the "authentic context" (J. Brown et al., 1989) was clearly demonstrated (akin to a practitioner visiting a new site for a project or carrying out a post-occupancy evaluation). Other case studies were satisfied with physical model representations of spaces and the qualities they were able to represent in a less obviously, "situated" context such as Traverso's (2015). In Stannard's lighting workshops the working physical scaled model represented, "situated" (J. Brown et al., 1989), real spaces, that could be imagined through their physical, spatial qualities as the student interacted with it physically and visually.

In the more recent examples, virtual environment representations and digital visualisations in (Andersen & Paule, 2011) were prioritised for their "optimisation", accuracy and range of daylighting results, rather than their "situatedness". However, the student work addresses the real *and* virtual environment of the given space, indicating that a level of "situatedness" was still present. In Traverso's (2015) model investigations, the experimental spaces were called "deliberately abstract" aligning more closely with a "non-situated" approach (J. Brown et al., 1989) yet the "situated" atmosphere of the modelled space was clearly demonstrated and could be engaged with experientially . These variations in case studies in relation to “situated” learning define a range of views of experiential learning, not always conforming to the constructivist situated learning description defined by (J. Brown et al., 1989) (Boud et al., 1993), yet relevant nonetheless for their experiential didactics. These findings were considered important for the creation of this research study and helped define where and how the workshop scenarios would be “situated” in relation to selecting case study buildings, didactics for investigation and research locations.

The following table summarises the pedagogical approaches included within this review and proposes ontological perspectives for each:

Daylight explorations Type A
Purpose (Design Knowledge Acquisition) for the intervention of sunlight in architectural spaces and development of formal architectural geometry, armature and fenestration Output – physical scaled models, virtual models, hand or computer drawings, photographs and virtual fly-through Ontology – technical basis for sunlight Value of daylight – solar path influences formal geometries, fenestration and site orientation
Daylight explorations Type B
Purpose (Design Knowledge Acquisition) for increased understanding of lighting ambiance Output – physical scaled models, hand drawings, photographs, descriptive textual outputs Ontology – light as aesthetic element

Value of daylight – experiential, daylight evokes feelings within an architectural space
Daylight analysis – Type C
Purpose (Design Knowledge Acquisition) for environmental assessment of solar gain, glare, louvre design and daylight availability Output - most commonly as metrics through numerical outputs in charts or graphs or plan drawings populated with numerical data points Ontology – technical basis for quantitative assessment Value of daylight – a free natural resource used for lighting visual tasks and improving human comfort

When examining these pedagogical methodologies for teaching daylight described within research papers and, further to a review of the current texts for architecture and interior design students (taken from higher education reading lists in Edinburgh architecture and interior design courses), it can be noted that the majority of these sources consider daylighting design as an individual subject with its own specialist language.

Daylight is frequently identified as a single elemental component of the architectural design through an assigned chapter (in a text book), an individual course (curriculum design) or analysis technique, as a quantitative, scalable value (within the design process). Many of the case studies highlighted in this chapter (Part B), use this definition to inform their methodological approach i.e. they accept an individualistic view of light in a space and try to use this within the study of whole space composition. Many of the case studies categorise these processes as such.

A further separation of daylighting from the holistic design process is evident in the analysis of the case studies. A clear distinction is apparent between exploring daylight within the design process during the generation of concepts and the separation of daylighting analysis for a chosen idea. Although numerical daylight analysis was identified as an important task within the design process (all case studies included it to some extent), in most situations it was not dealt with in a similar way to that of the practicing designer in a real project situation. In the educational context within which the case studies were situated, suspension of many of the other elements of the design process were permitted whilst the daylighting aspect was analysed. The discovery of daylighting behaviour and the analysis of this was the main focus of the participant.

These case studies also highlight the placement of daylighting ‘analysis’ at the end of the project. “Optimisation” of daylighting design is a large and controversial field and therefore a full review of this theme has not been included as it would be out with the scope of this study. However, it is relevant for this study to note that lighting ‘analysis’ is apparently aligned with this quantitative ontological approach supporting that numerical verification is the only demonstration of lighting analysis. Although this quantitative analysis is understood to be important by the majority in the field of lighting, lighting ‘analysis’, by its very nature, aligned with complex and accurate optimisation approaches can no longer place value on daylighting discoveries carried out during the first iterations of the design process. Iterative ‘reflection’ is clearly assigned a different role and value to that of ‘analysis’ and this perspective serves to widen the divide between qualitative and quantitative ontological perspectives for daylight.

With these varied ontological perspectives outlined through the case studies, it is apparent that the skills and knowledge set expected of the daylighting designer are defined differently within each case study included here. This suggests that these skills are flexible and dependent on the ontology of the academic instructing the student group but also highlights the opportunity for fluidity in this regard to suit emergent and evolving design issues.

In the published case studies, few instances have been captured where qualitative and quantitative ontologies for daylight (or lighting more generally) have converged, even although much of the discussion in the outlined approaches argued for this. The next section of the thesis therefore develops this evident gap in pedagogical approach, to find further solutions for effective converging of these disparate ontologies for daylight. This is approached through investigating other domains dealing with similarly complex ontological scenarios. It outlines the methodologies used in three alternative creative fields; theatrical lighting and set design, music composition and textile design and weaving. With each methodology outlined, the suggested application within the context of this thesis study is proposed.

2B.6 How can the methodologies of theatrical lighting pedagogy provide insights into a synthesized approach?

> *In the design phase of a production, the set designer or costume designer can offer a model, or sketches and swatches, which, though not fool-proof, do provide enough information for a meaningful discussion to ensue. The sound designer can play actual cues. The lighting designer has no such means of communication. There must be great reliance on words.*
>
> *(Strawbridge, 2003), p. 38.*

Strawbridge, a renowned professional theatrical lighting designer and educator within the Design Department at the Yale School of Drama highlights that the descriptive words and language used for lighting, and in this domain specifically, theatrical lighting, can be difficult to master, particularly due to the fact that "words can be misleading" (Strawbridge, 2003). He questions if the meanings of the descriptive words used by design directors and designers in the theatre workshop can really have common meaning, or a common understanding as there are clearly opportunities for alternative interpretations.

> *Does "hot" mean red, hellish light, or intense white daylight? Are we talking about the light on the figure or the background? It is hard to know without a context, and the context will not exist until everything comes together on stage.*
>
> *(Strawbridge, 2003), p.39.*

This scenario, taken from a theatrical lighting context, can be directly compared with the discussion and description of light in architectural lighting contexts too. Strawbridge alludes to the positive nature of this need to understand the language of light when designing for the theatre as through the methods and processes required to do this the design can have more clarity and precision. It can be proposed that the specific words used may vary between lighting disciplines but within each field a common understanding can take place if tools are used that allow parallel or translational approaches. This allows for multiple ways of understanding and translating the concepts that the lighting descriptor may make available.

To aid early discussions in this part of the design process Strawbridge suggests the supplementation of descriptive words with other design tools to bridge any misunderstandings through a clear understanding of context. However, he suggests that 3D tools are most helpful in this respect as “Lighting is three-dimensional” and a “picture is two-dimensional” and therefore cannot convey the full proposed effect from various viewing positions (Strawbridge, 2003), p39.

> *There is a temptation to believe that using paintings or photographs as references will get us beyond the difficulty of relying on words, but caution must be exercised. What one person sees or responds to in a picture may be quite different from what another sees or responds to…A still from film noir may speak to one person because of its high contrast and to another because it is monochromatic.*

In theatre design, 3-dimensional physical representations of theatre sets are commonly used, with small artificial lights to demonstrate and ‘translate’ the atmospheric ambition. This physical, scaled, stage set model is by no means similar to an architectural scale model in that it is used for creation of the final design realisation rather than as representing an idea or intent. The materials used in theatrical models are selected as exact replicas of texture, scale and colour and alongside a few layout drawings serve to be the generators of the full-scale set design. The lighting is often represented to provide an overall effect and this is not scaled as such in the model (precise locations and beam widths are not represented commonly). In architecture and interior design, the architectural model serves as a part of the full package of information and alludes to volumetric studies, technical structural proposals or colour studies, rarely demonstrating the texture or scale of the materiality in any authentic way.

The use of a scaled model in theatre is therefore incredibly useful and adds to the understanding of lighting that is possible through a specific framing. When we add lighting to a theatrical model we can stand back and view the scene from a specific viewpoint, that of the audience, which is more often a known, fixed seating arrangement. Here the architectural model can be viewed as a very different proposal. Within architectural interior spaces the building user may approach from many directions, may sit or rest in variable positions and, crucially, it is unlikely that the user's previous exposure to light can be speculated. Although a theatrical model allows compositional changes and a journey through an architectural interior can also provide this change is scene (composition) it cannot create a sequence of settings to be experienced in a certain order with any real assurance. The adaptation of the eye is altered with the movement from outside to inside and the dynamic penetration of sunlight into the interior.

Strawbridge notes that some directors are very good at stating what is required in a design using descriptors that are describing the concept but avoiding dictating the technical solution that can allow this to happen. For example:

> *They may use adjectives like "clinical" or "voluptuous," but not terms that suggest a technical solution, like "white down light" or "blue backlight."*
>
> *(Strawbridge, 2003), p.39.*

However, he also highlights that it is not simply a case of describing the theatrical lighting proposals in terms of atmospheric descriptors. Every lighting design idea is based on a structural proposal, providing sequences or a conceptual ordering that will allow the atmosphere to be achieved.

> *It is not widely appreciated that lighting needs framework, a structure. Once this basic skeleton exists, it can then be fleshed out in any number of ways; but unless the structure is complete, the lighting design won't have integrity or depth.*
>
> *(Strawbridge, 2003), p.39.*

This structural basis does not, it seems, allude to a conceptual atmosphere with little reference to lighting principles or technical understanding but instead a qualitative approach that has a strong structural understanding. It can be seen that the design for theatrical lighting is informed in a specific way, with aesthetic first and quantitative measures after. This allows for the creation of atmosphere through the integration of the holistic design to take shape with the lighting playing one of many roles in that atmosphere. Through one-to-one experiential training in the theatre, designers can translate the small scaled model to the full-size stage, delivering the atmosphere through technical rigour, learned through a discipline specific heuristic approach.

This insight was transformative in my understanding of theatrical lighting as it brought to the fore the idea that design heuristics, most often applied to product design had some significance in the design of lighting and must be reviewed in this alternative context. Daylight in particular has inherent structures and sequential patterns affected by location, climate and time of day or night that can provide a valuable framework with which to base any interior atmosphere proposed. Additionally, the heuristic nature of designing with theatrical lighting that Strawbridge highlights *in combination with* verbal descriptors is known to reduce misunderstandings in this specific context that demands challenging interpretation of atmospheric concepts. He elaborates on this mixed methodology for conceiving and realising a theatrical lighting design concept through the benefit of shared experiences and references.

> *For a director and lighting designer to know that they are truly speaking the same language, it is necessary to have a track record, a bit of shared history. Having worked together before, a team will have a common vocabulary. The ambiguity of terms and expressions used to talk about light will be much less of an issue. Fewer words will be required. There was a period of years in which the director Travis Preston, the set designer Christopher Barreca and I did many shows together, and we came to understand each other well. In what I feel were the most successful of our collaborations, the distinction between lighting, set and staging, as well as clothes and sound, no longer applied. Everything worked together as part of one unified whole. Our communication reflected this: Lighting ideas could come from any of us, as could ideas about the set, the casting or anything else*
>
> *(Strawbridge, 2003), p.40.*

For the architectural practitioner the "Community of practice"(Wenger, 1998) with which they identify with may have a shared common language through visual or verbal descriptors and references. Yet, in some circles this may not be fully developed or limited in scope or richness with regard to daylighting. For those "novice" (Strawbridge, 2003) designers who have yet to integrate into any specific CoP or those who are starting out in design training, a shared language is less accessible and shared references and experiences will be restricted. Strawbridge suggests that this situation is very problematic when designing with light, "Without that frame of reference, the discussion of lighting is just too abstract" (2003). However, he suggests that developing the aspect of shared history when designing with others can provide significant benefits. It is proposed that this sharing of understanding can happen within daylighting design contexts if designers have the opportunity to visit and create spaces together through experiential methodologies, in turn learning and applying appropriate heuristics, through developing a common language.

In summary, considering this theatrical lighting methodology has exposed a qualitative yet technical understanding of light that underpins design work and conceptual creation within the discipline. For this research study it was therefore decided to test similar approaches to designing with daylight through shared experience, creation of a CoP language and combined 2D, 3D visual and verbal descriptors and models to create the desired interior daylit atmosphere. Strawbridge, when discussing theatrical lighting, emphasises that it is fundamentally important that, "The elusiveness of the topic requires that we stay open to any and all means of communication". It was therefore assumed that many means of communication (methods) in the development and analysis of the research study would be necessary.

2B.7 How can William's pedagogical methodologies for music composition provide insights into didactic methods for teaching daylighting?

> *[Music] composition is a complex task that requires the simultaneous management and solution of several interrelated problems.*
>
> *(B. J. Williams, 2010), p. 122.*

Music composition pedagogy is a complex field that seems to defy codification (B. J. Williams, 2010). The idea of the composer as a creative 'genius' that arose during the eighteenth and nineteenth century changed the field forever and is comparable to that of the architect as creator and artist (Burr & Jones, 2010), known to have elusive and frequently exclusive, conceptual aspirations (Mallgrave, 2010). Music composition has a historical divide between music composition and music theory and its pedagogical implications. Over time, the "technical exercises for the teaching of music composition have been relegated to the domain of music theory apart from the creative field of composition" (B. J. Williams, 2010). This description aligns with the field of spatial design and its relationship with its perceived 'technical' subjects such as daylighting (as described in Chapter 2B.6).

Williams (2010) proposed pedagogical methods for musicians dealing with the creative and technical aspects of composition to ensure “neither pursuit would remain isolated from its interrelated counterpart”. He developed two key pedagogical ideas in relation to students learning music composition, applicable to this research study in the context of daylighting.

The first is that of the clarity of the case study and the concept being explored. The case studies here are defined as the source given as inspiration such as a composer’s work or a genre of music. He recommends defining boundaries for stretching the learner’s understanding of the concept (giving an appropriate limitation or set of limitations) without over complexity or lack of boundary leading to and allowing wrong assumptions around the threshold concept under exploration.

> *A high level of restrictiveness will help students better appreciate various features of a given style as they interact with its boundaries. Conversely, a high level of permissiveness may result in the construction of erroneous internal models that will be more difficult to correct once in place.*
>
> *(B. J. Williams, 2010), p.100.*

This idea of boundary was demonstrated in the pedagogical case studies included within this chapter with some educators allowing a limitless boundary and others applying tighter constraints. With William’s pedagogical approach in mind, it was therefore decided that the briefs used for this research project would require clarity in the boundary of the task set. To ensure success in use they would also need to allow some freedom in the methods used to explore the behaviour of daylight in spatial compositions. However, it was also decided to include a requirement for reflections at each stage of the brief to ensure quantitative and qualitative assumptions were developing without misunderstandings caused by over complexity of the didactic task set.

A further idea of Williams influenced this research study design methodology. He proposes that :

a) *A course in basic composition should therefore focus on the development within the students of a familiarity with musical materials that may be later used for truly novel production.*

(B. J. Williams, 2010), p.100.

b) *By using pre-composed melodies, the compositional problem is limited to and focused on the composition of accompaniments, transitions and developments. [C]lassical-style piano accompaniments would have been studied by this point in the theory curriculum, further limiting the problems to be solved.*

Parker Sylvia Parker, "Understanding Sonata Form through Model Composition," Journal of Music Theory Pedagogy 20 (2006): 119–137. As influencing the studies of Williams (2010).

Williams therefore suggests that if the pedagogical approach ensures learners have familiarity in task methods or materials used, in this specific research context, this would encourage a basic understanding to develop that can then be applied to future spatial design scenarios or creations. Additionally, in the context of this research study using daylighting, the inclusion of existing or "pre-composed" spatial designs will also focus concentration on the behaviour of daylight as the learners will be mostly familiar with the context and sources (the case study building or site, the tools, methods or physical items) used for the tasks.

Although Williams' pedagogical approaches originated from a different field, music composition, the similarity of the pedagogical relationships between technique and creativity identified was appropriate and useful in the alternative context of this research study. When reviewing William's "Technical competencies for Music Composition" (2010) it became apparent that the competencies he proposes for learner musical composers are particularly relevant to this research study due to the nature of composition and the need to engage with relational, technical yet creative scenarios. The technical competencies of "Clarity", "Coherency", "Idiomatic" understanding and "Orchestration" of the disciplinary concepts can, in his opinion, integrate successfully with creative exploration. His perspective, aligning appropriately with the learning of daylighting design, suggested a theoretical underpinning for a pedagogical approach for this research study.

I responded to this insight by studying William's (2018) outline and creating a proposed list of Daylighting Design Competencies defining these four competencies in relation to daylighting pedagogy and practice (see Chapter 4 for full details).

These competencies formed the basis for exploration of daylighting concepts within the workshop tasks. They sought to providing an overarching methdology (further details in Chapter 4) to underpin *an approach* to a daylighting problem, (as Hein (1991) suggests a truly Constructivist approach should encourage), rather than capturing a set of technical facts or fomulated solutions that cannot easily be applied in future design contexts if the approach is not understood.

2B.8 How can an awareness of "domain-general" knowledge and "domain-specific" knowledge allow overlapping of ontological perspectives in daylighting pedagogy?

Seitamaa-Hakkarainen & Hakkarainen (2001), carried out a series of protocol studies with two novice and two expert designers in the field of weaving design. Their findings are of relevance to this study as they provide insights defining how both novices and experts dealt differently with the visual *and* technical aspects of the design process. They also highlight how an awareness of the application of appropriate methodologies for the "domain-general" and "domain-specific" knowledge of a discipline plays a large part in the synthesis and broadening of a designer's ontological perspectives.

> *Weaving design may be divided into two problem spaces: composition space, which represents visual designing; and construction space, which represents technical designing. The former space represents more domain-general knowledge of visual composition while the latter requires the domain-specific knowledge of production of woven textiles… A close interaction between the two design spaces appears to be a necessary prerequisite for successful weaving design.*
>
> *(Seitamaa-Hakkarainen & Hakkarainen, 2001), p48.*

Seitamaa-Hakkarainen and Hakkarainen (2001) found that the experts were able to work with the visual and technical elements of weaving in parallel, during the design process, moving between the 'composition space' and the 'construction space'. In contrast, they discuss their observations of novices' processes based in the composition space (visual ontology) and only occasionally jumping to the construction space (technical ontology) to explore how visual ideas could be realised through the technical approaches to weaving.

Additionally, they found:

> *Serial processing (Gero & Kannengiesser) designing is carried out by considering only one problem space at a time, i.e. a designer first tries to solve a visual problem, and after that moves to the problem of construction of visual ideas. Parallel processing (Gero & Kannengiesser) a designer considers both visual and technical aspects of a design problem in a given period of time; these aspects of design are more integrated.*
>
> *(Seitamaa-Hakkarainen & Hakkarainen, 2001), p48.*

They relate "serial processing" to novice designers as a less successful approach to those with more experience in the field using a methodology of "parallel processing" (Seitamaa-Hakkarainen & Hakkarainen, 2001). Therefore, it was understood that if this research study seeks to identify methods to improve a novice designer's understanding of daylighting concepts through both the qualitative and quantitative connections and approaches, it is important that pedagogical methods for "parallel processing" (Seitamaa-Hakkarainen & Hakkarainen, 2001) are introduced, carried out and evaluated. Visser (2006) discusses the importance of the type of knowledge domains within which the designer is working, influencing the activity that is taking place at that time.

On the surface this idea implies a simple relationship between the task and the concept being learned, but, it actually suggests many other aspects within the pedagogical approach that need consideration. The connection to the knowledge domains within which the designer is working within is significant. The tasks and their associated knowledge domain can further influence the ontological perspective of the designer, that of further separation between qualitative and quantitative or by demonstrating a more holistic approach.

In conclusion, the findings from the review of Seitamaa-Hakkarainen & Hakkarainen's pedagogical insights suggested tasks within pedagogical constructs that allow novices to engage with daylighting activities from both qualitative and quantitative domains may support more advanced understanding of the design domain and are therefore to be encouraged.

It was therefore decided to explore the idea of the familiar "domain-general" knowledge to inform and encourage acceptance of the less familiar "domain-specific" knowledge within the pedagogical methodology for this research study. Engagement with “parallel processing” (Seitamaa-Hakkarainen & Hakkarainen, 2001) requires understanding of each ontology and application of its associated methods within the specific design field. Therefore, in the context of this research study, engagement with parallel or joined up design thinking through both quantitative and qualitative ontologies within daylighting, demanded pedagogical approaches emphasising familiar processes through the methodology and the aligned workshop methods.

2B.9 How can an awareness of existing pedagogical approaches inform advancement of the field of daylighting?

In conclusion, findings from this pedagogical review have been both stimulating, inviting further research challenges, yet complex to gather and define. It initially seemed that existing teaching ontologies, defined by pedagogical approach, could be polarised as holding either quantitative or qualitative perspectives. In hindsight, these parameters were too restrictive and a specific ontological perspective was impossible to define. The overlaps apparent within the pedagogical case studies presented were consistent yet varied in the methodological approach. Where this insight was most useful however was in the discovery of these overlaps.

The first part of the chapter defined the polarised attitudes to daylighting within spatial design pedagogy and the positioning of daylighting within many design courses. However, when considering the published pedagogical approaches, (those educators who had actually tried to break from this mould were the ones who had chosen to publish their work), it became apparent that overlapping ontologies for the teaching of daylight existed in the many diverse pockets of design education. The knowledge and skills the educators wished the students to have were closely aligned; an aspiration for students to grasp an understanding of the behaviour of light through experiential discovery and the use of analytical techniques and processes for daylighting design. None of the pedagogical case studies defined these overlaps with any measured analysis through benchmarking student success and no agreement over course curriculum or methodology could be found. However, the overlapping areas demanded more exploration as it was here that potential for a more holistic epistemology for daylight could be found. These overlaps appeared to provide the most dense and limitless opportunities for “think[ing] differently” (Holl, 2000) p.13. to occur. Consequently, this thesis continues to define how these ontological overlaps for daylighting design were tested, measured and defined through iterative investigations in educational contexts in order to propose an advanced methodological approach to the teaching of daylighting.

The next chapter addresses the “domain-general” and “domain-specific” knowledge that Seitamaa-Hakkarainen & Hakkarainen (2001) proposed as key in progressing overlapping of these domains. Chapter 3 outlines information collected from both design student participants, practitioners and daylighting texts to define current understanding, gaps in knowledge and motivations for working with daylight within spatial design.

Chapter 3 Pilot Studies

3.1 How can we develop an understanding of the 'value' of daylight in architectural contexts?

> *It is hard for us to specify the characteristic of a feeling without descriptive concepts of a spatial nature.*
>
> *(Hippius 1936: 315) in (Griffero, 2014)*

On first consideration of daylighting and the corresponding issues surrounding designing with it in spatial design contexts, a recurrent issue arising in conversations with architects and students of architectural design about daylighting was the complex language, or 'terminology' relating to quantitative metric measures (refer to Chapter 2 for examples of these).

The use of daylighting metrics within architectural design is still limited (Lewis, 2015, 2017) and the notable reason that many architectural designers give for not using these metrics relates to the confusing "terminology" or "technical vocabulary" (Reinhart & Fitz, 2006). In order to use and ultimately understand the results of daylighting analysis the vocabulary or specific terminology must be understood to appreciate the consequences of the outcome. In fact, in order to use any daylighting analysis software, it is critical to understand the input vocabulary as much as the output.

Disagreement over a defined daylighting vocabulary is not a new issue. After conducting a survey of interior design textbooks in US schools of design, Brown (2004) noted a persistent inconsistency between the vocabulary used to describe and evaluate spatial compositions and the terminology used to discuss light. Attempts to work towards a more common vocabulary were highlighted after a survey conducted by the National Research Council of Canada during the summer of 2005. The survey of more than 150 architects and engineers worldwide presented five alternate definitions of daylighting.

Each definition emphasized one of the following aspects: user comfort, electric lighting energy savings, overall building energy savings, peak energy demand reduction, or general economic benefits. Participating architects prioritized user benefits while engineers prioritized energy savings and economic benefits but few participants discussed lighting metrics terminology. (Wymelenberg, 2008).

To investigate this issue further and underpin and validate the emerging research questions a research design was created, with contextual explorations into two key areas:

- Existing daylighting textbooks and online journals for practitioners and students
- Pilot study questionnaires investigating use of daylighting design (for practitioners and spatial design students)

3.2 What issues emerged relating specifically to the use of daylighting language in daylighting texts?

As a brief pilot study within this larger research agenda, and to better understand the familiar language spatial designers are exposed to and the contexts within which 'design' language and specialist 'lighting' language are used, a selection of daylighting textbooks from both environmental and design perspectives and architectural journals were analysed. This study collated a series of text sources from spatial design course reading lists (UK HE Institutions). The most relevant chapter or a minimum of ten pages from a journal relating to daylight/lighting/spatial design were selected. This list included the top ten articles from Dezeen on-line journal, Arch Daily searching under the term "daylight' for each. These were voted the most popular on-line journals by the spatial designers responding to the questionnaire (see next section for details of questionnaire).

The identified texts were scanned then exported into Microsoft Word format. Each chapter or article was then imported into NVivo. NVivo was selected as suitable software to use for analysis of these data as only simple text analysis was required, yet some features within the software allowed efficient coding and word count/frequency options. This analysis method was used to input text-based data and highlight the frequency of language use or descriptive text words. A "word query" was undertaken for each of the selected texts to produce outputs as a visual "Text Tree" that could be used for comparison against other “word trees” (see below for example sheet with the source name and word tree). The full set of results is included within (Appendix 3).

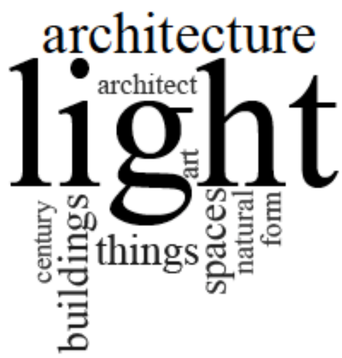


Figure 6 (Left): Word Tree - Tregenza (2011) *Figure 7 (Right): Word Tree – Plummer (2009)*

Although the exercise was limited in scope, as the number of texts analysed was a selection only of the expansive range of sources within the field of spatial design, they were a useful source of data nonetheless. They assisted in the development of my understanding of the ‘categorising’ of responses in relation to ontological perspectives. Strong patterns of recurrent language emerged from the data relatively quickly. These data indicated that the groups of 10 most common words from each text, when grouped together for categorisation, strengthened the argument that each source could be defined as aligning with either a qualitative or quantitative ontological perspective.

It was found that technical daylighting language was frequently used in all the daylighting textbooks analysed, yet seldom ever in the architectural press.

Word	Length	Count	Weighted Percentage	Similar Words
lights	6	462	3.12%	'light, light, light', lighted, lighting, lightness,...
buildings	9	120	0.81%	build, building, building', buildings, builds
design	6	104	0.70%	design, designate, designed, designer, desig...
architecture	12	90	0.61%	'architecture, architectur, architectural, archi...
rooms	5	87	0.59%	room, rooms
walls	5	85	0.57%	'wall, wall, walled, walls
houses	6	85	0.57%	hous, house, housed, houses, housing
windows	7	79	0.53%	window, window', windows
daylighting	11	77	0.52%	'daylight, daylight, daylighting
one	3	71	0.48%	one, ones

Figure 8 Architecture texts - top 10 words

Word	Length	Count	Weighted Percentage	Similar Words
lights	6	116	3.76%	'light, light, light', lighting, lights
design	6	53	1.72%	design, designed, designer, designers, desig...
space	5	53	1.72%	space, spaces
building	8	37	1.20%	build, building
using	5	31	1.00%	use, used, uses, using
interior	8	27	0.87%	interior, interiors
galleries	9	25	0.81%	galleries, gallery
create	6	25	0.81%	create, created, creates, creating
new	3	21	0.68%	new
museum	6	16	0.52%	museum

Figure 9 Interior Design texts - top 10 words

Word	Length	Count	Weighted Percentage	Similar Words
lighting	8	95	1.95%	light, light', lighted, lighting, lights
illuminance	11	69	1.41%	illuminance, illuminances, illuminate, illumina...
daylight	8	66	1.35%	daylight, daylighting
sky	3	62	1.27%	skies, sky
window	6	39	0.80%	window, windows
using	5	37	0.76%	use, used, using
luminous	8	31	0.64%	luminance, luminances, lumination, luminous
levels	6	29	0.59%	level, levels
glare	5	27	0.55%	glare, glare'
visual	6	27	0.55%	'visual, visual

Figure 10 Environmental Design texts - top 10 words

Word	Length	Count	Weighted Percentage	Similar Words
lights	6	629	3.40%	light, lighted, lighting, lightness, lights
daylighting	11	274	1.48%	'daylighting, daylight, daylighted, daylighting
design	6	205	1.11%	design, designate, designed, designer, desig...
buildings	9	168	0.91%	build, building, buildings
windows	7	135	0.73%	window, windowed, windows
using	5	120	0.65%	use, used, useful, uses, using
sky	3	114	0.62%	skies, sky
spacing	7	113	0.61%	space, spaces, spacing
illuminance	11	103	0.56%	illuminance, illuminant, illuminate, illuminated...
directly	8	102	0.55%	direct, direction, directional, directionality, di...

Figure 11 Lighting Design texts - top 10 words

Word	Length	Count	Weighted Percentage	Similar Words
design	6	76	2.39%	design, designed, designer, designers, desig...
light	5	65	2.05%	light, lighting, lights
daylight	8	58	1.83%	daylight, daylighting
space	5	35	1.10%	space, spaces
architects	10	34	1.07%	architect, architects
buildings	9	29	0.91%	build, building, buildings, builds
using	5	27	0.85%	use, used, useful, uses, using
openings	8	22	0.69%	open, opened, opening, openings, openings'
level	5	21	0.66%	level, levels
visual	6	21	0.66%	visual, visualization, visualizations, visually, v...

Figure 12 Spatial Design texts - top 10 words

The architecture books used words that described the architectural elements most frequently with no ‘technical’ lighting words included in the top ten. The interior design texts were similar, although included spatial typologies that require lighting as a key element; “galleries” and “museums”. The design journals included similar words, pertaining to building elements, “space”, “levels” and “openings”.

The environmental design texts included words relating to a different ontological perspective such as “illuminance” and “glare”. These ‘technical’, words were not included within the previous design texts and allude to CoP values in metrics and measurements of light. Finally, a review of the daylighting texts highlighted a combination of words relating to both the lists generated by the architectural and interior design texts and the environmental design texts, although words were generally more related to lighting strategies such as “sky”, “daylighting”, and “windows”. “illuminance” was consistently used in these texts though it appeared alongside architectural elements such as “windows” and “spacing”.

This study of textbooks and on-line daylighting articles was proposed to consolidate my hypothesis, proposing that language used for daylighting design and the frequent use of technical terminology does not align with or integrate familiar spatial design language and therefore creates a barrier separating spatial design and daylighting design.

This review found that daylighting texts and environmental design texts were clearly separated by ontological perspectives aligned with qualitative or quantitative aspirations and values for daylighting. These texts on daylighting therefore do not provide an easy reference for the spatial designer, accustomed to reading the texts as noted in this study. Technical, quantitative ontologies for daylight as demonstrated in the sources analysed do little to integrate with familiar spatial design journals, textbooks and their recognised qualitative ontologies. Technical daylighting texts may therefore be viewed as unfamiliar and less relevant within the design process than other spatial design texts offering familiar epistemological perspectives, aligned with spatial design communities of practice.

However, I also propose that daylighting language is not too technically complex for spatial designers to understand. The lack of engagement with technical language is not a straightforward issue of competency of numerical skills, but rather, daylighting terminology requires specific understanding of the behaviour of daylight in order to be understood successfully. A designer's competency in understanding and relating daylighting design concepts within the holistic view of a spatial design is the key challenge needing to be addressed. Without these connections and sufficient understanding driving motivations towards designing with daylight, the language of daylight resides cautiously on the periphery of the common vocabulary of spatial design and design process.

3.3 Research design and methodology introduction for questionnaires

To investigate this further with empirical data, practitioners' questionnaires were created as part of the pilot studies:

- **On-line questionnaire for spatial design practitioners, herein referred to as 'Practitioners' Survey'**
- **Paper format questionnaire for spatial design students, herein referred to as 'Students' Survey'**

For both participant groups the questionnaires sought to identify emerging themes, the "chief concerns" (Glaser, 1992) and reveal the understanding 'or otherwise' of contemporary architectural representation of daylighting principles using qualitative and quantitative methods. The questionnaire was created to provide data that aimed to support the following:

- Insights into participants' "chief concerns" with regard to daylighting within spatial design
- Insights into the use of current daylighting tools and experience of this

- The role of intuition in designing with daylight
- Indications of motivations within design processes in spatial design and alignment with daylighting design
- Insights into the daylighting knowledge base in spatial design “communities of practice” - understanding of daylighting regulations/rules of thumb/threshold concepts (Practitioners’ Survey) or terminology (Students’ Survey’)
- Discussion of designers’ motivations for working with daylight, revealing distinct ontologies for daylighting design.

The Practitioners’ Survey was considered important for this research study to determine the appropriate lens for this research project and ensure the research question findings would assist in the advancement of spatial design pedagogy with regard to daylighting, relevant to professional design demands. It was carried out in the form of an online questionnaire. This questionnaire sought to expose current paradigms and ontological understanding of daylighting design within existing UK spatial design communities of practice.

It was proposed that qualitative methods were used to collect the necessary data based on the “Community of Practice” (Wenger, 1998) participants’ opinions on daylighting. Qualitative methods were used to provide opportunities for non-binary formatted questions in the pilot study questionnaires. This question type was included to encourage qualitative responses and permit a variety of different visual descriptors of daylight.

The questionnaire provided case examples of lit interior spaces and opportunities for practising architectural designers and researchers to explain their ontological and epistemic perspectives, through written responses to visual representations of a set of daylit architectural scenarios. The questions sought to gain insights into the understanding of daylight through the methods by which daylight was represented within their design vocabulary (approach, analysis discussion, visual representation and descriptive language).

It was anticipated that the data collected would determine if a designer’s representation and interpretation of daylit scenarios could reveal the particular understanding of daylight that a designer held. This would then, in turn, reveal their alignment with a particular ontological understanding or epistemic approach to daylighting. It was considered to be important, before commencing this research study fully, to understand what spatial designers’ ontological perspective of daylighting was and why this epistemology was predominant.

The Students' Survey included a set of general questions about daylighting, previous educational experience, its value and importance in design and confidence in using daylight within spatial design projects. The final part of the questionnaire requested a drawing or written description of various lighting terms to clarify the existing technical knowledge of the student.

These two questionnaires were aimed at (i) professional architectural designers (113 total UK participants) and (ii) spatial design students (60 in two groups of 35 no. + 25 no.) in 2015-16 and 56 in two groups of 27 no. + 29 no. in 2016-17 from interior design courses over 2 consecutive years.

3.3.1 Developing the Questionnaire – Framework for Questions

Questionnaires were developed using a 'mixed method approach'. Both the spatial design student participants' questionnaires and spatial design practitioners' questionnaires were intended to reveal informal and formal daylighting knowledge of the participants' through a combination of closed, and open-ended questions and sequenced as indicated.

Closed questions were used to gain factual understanding of various, related topics. This included: the participant's role in design practice, the role of daylighting within their own practice and in the second part of the questionnaire, understanding of numeric lighting data with objective 'correct' or 'incorrect' answers (transfer of knowledge - objective lighting principles). This question type was employed as a single or multiple-choice question to correspond with the objective information being addressed and analysed.

Open-ended questions were used to explore less defined areas of the research questions to ensure participants were able to respond in ways that reflected their answers more fully. It was also expected that this would encourage opportunities for new ideas, meanings and insights to develop from the findings. Additionally, within the questions created responses to visual sources was requested, using open-ended questions encouraging descriptive answers. Finally, it was proposed that the descriptive text used by participants could be analysed quantitatively to produce a lexicon of language used in the "Community of Practice" under analysis.

3.3.2 Translational Explorations – The Practitioners' Survey

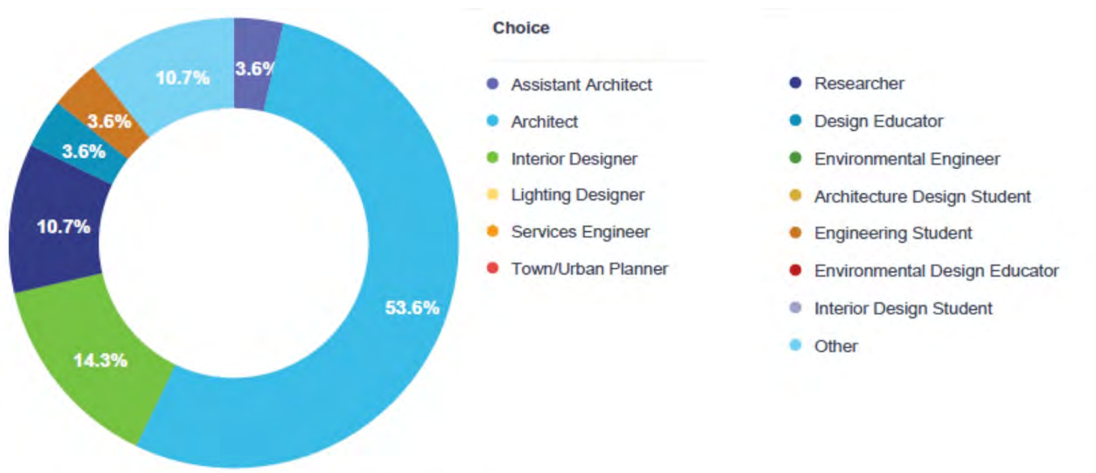
This section first reports on the findings from a questionnaire of over one hundred spatial design professionals in the UK. As the questionnaire was initially created to explore the common knowledge base across varying scales of architectural practice and communities it was decided to send out the questionnaires to the many design practitioners I had worked with or knew of practising throughout the UK. A link to the survey was distributed via email to 19 practitioners and further distribution was undertaken indirectly. These strategies of indirect distribution and voluntary completion were based upon similar strategies using questionnaires (Dekker et al., 2012; Dandy and Bendersky, 2014) and were employed to reduce biased perspectives and/or polarising the participant pool, given the degree of interest participants may have held in daylighting.

Questionnaire participants were asked to send on the link to the survey to colleagues or friends within the construction industry using invitation text, approved by the ethics committee, "You are invited to participate in a short anonymous survey about daylighting in architectural design. It will take approximately 10–15 min to complete." This was attached with a link to the survey which was entitled "Design Practitioner's Survey." Thus, the survey was not directly distributed by the author to every participant. Although the response was surprisingly generous using this method (123 total respondents from an original group of 19 email invitations) no data therefore exists defining the range of participants who did not respond to the invitation to take part in the survey. However, findings from this distribution method were preferable to distributing a survey that was expressly about daylighting to busy practitioners discouraging those who were less engaged with the concept, reducing the range of responses and balanced views possible. The survey remained open for 3 months and was closed when over 100 participants had fully completed the survey, to ensure a useful sample size. 120 participants completed the survey sufficiently for comparison out of the 123 respondents.

All responses were collected anonymously. The Practitioners' Survey was created using Survey Planet Pro, and all data responses were collected through this online service. Participants were provided with a web link for the survey and were encouraged to take part in the survey at any location with a computer, tablet or phone with internet access. When participants clicked on the provided link, they were immediately taken to a webpage containing a brief summary of the study and the consent form, and suggested ethical sequencing proposed and used by (Dandy & Bendersky, 2014) in their work with students and practitioners.

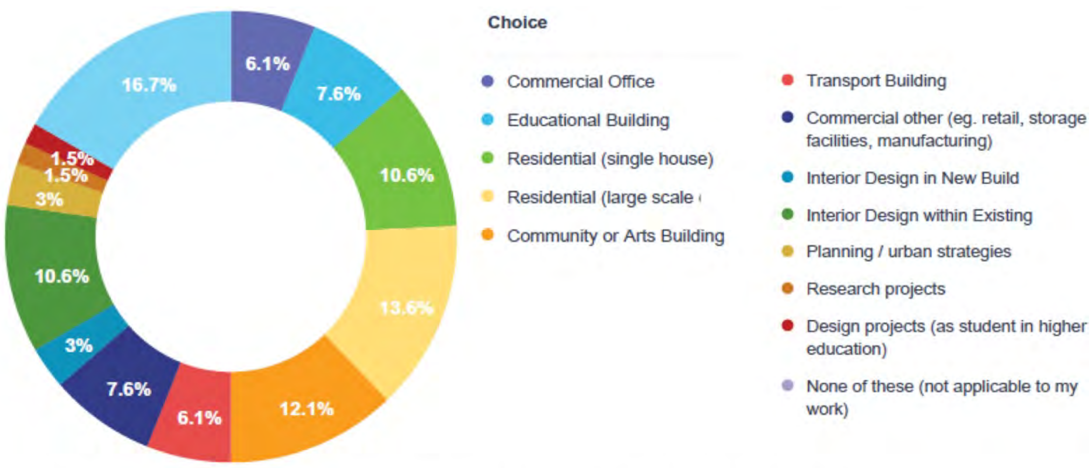
3.4 Summary of Results

Further to the consent form, participants responded to sets of branched questions, thereby reducing the time needed to complete the survey and to improve the relevance of the questions asked. The participant group was made up of various professionals from the field of spatial design, with the majority Architects and the second largest group Interior Designers.



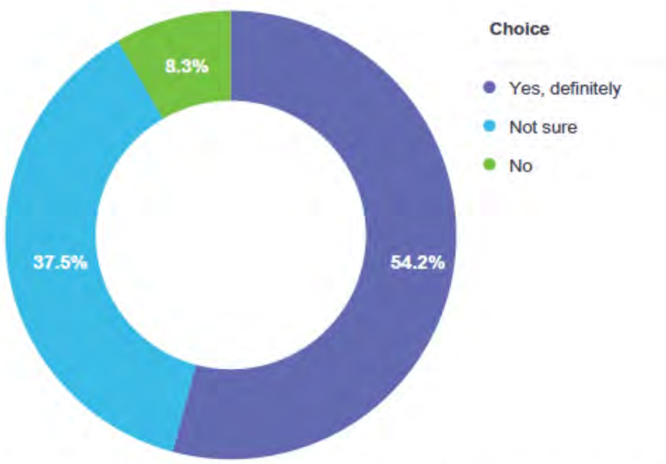
Q1: Please select your primary job description.

The majority of practitioners responding to the survey were involved with the design of residential buildings. This was an interesting insight as daylight was expected to be a large part of the designing of this building type. However, as can be seen below, the building types that participants responded as involved with was very varied and provided a good range of design scales, client types and priorities.



Q2: Please confirm the types of projects that you are currently involved with.

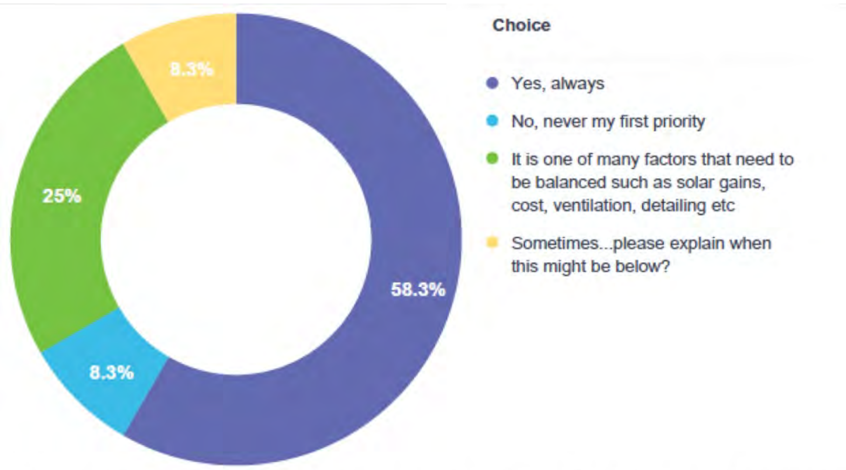
When questionnaire participants were asked about their lighting design knowledge, two questions emerged as providing particularly valuable insights into current use of daylighting concepts in practice. A question was created to assess the understanding of sunpath, the use of intuition or a clear technical competence in understanding solar trajectory either as local knowledge or an understanding of its application in unfamiliar contexts. Results showed that almost half of all participants were not confident in the use of or understanding of solar path (answering “not sure” or “no”).



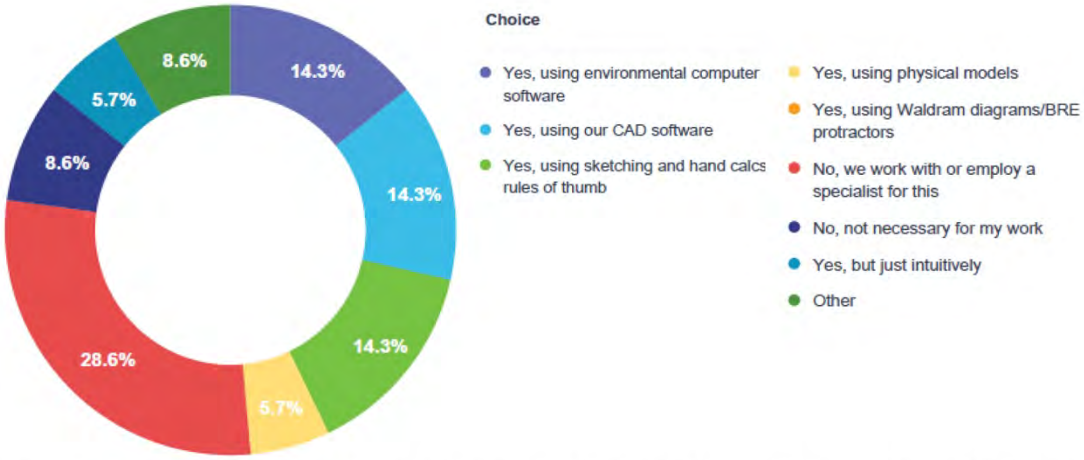
Q3: Would you be able to predict the location of the sun on a given day at a given time in a specific location and understand the shadowing of adjacent buildings?

Two of the additional comments in particular are worth noting as the responses highlighted that the designer responding to the question in each case thought it was of little importance to know the sun's path for a particular site or building, as 3D software (such as Sketchup) could do this for the designer. The retention of this daylighting concept was not viewed as a necessary skill.

The responses to a question created to give insights into the importance of daylighting within current spatial design practice were fascinating as more than half of the responses noted daylighting as a primary concern within their building design process, yet 30% of responses said they used a specialist to undertake any daylighting evaluations. On reflection these data confirmed this strange anomaly of: interest and importance in daylighting not aligning with an equal amount of engagement with it in practice. Further, designers who answered that they did get involved with daylighting or sunlight evaluations noted that they usually carried this out towards the end of the project.

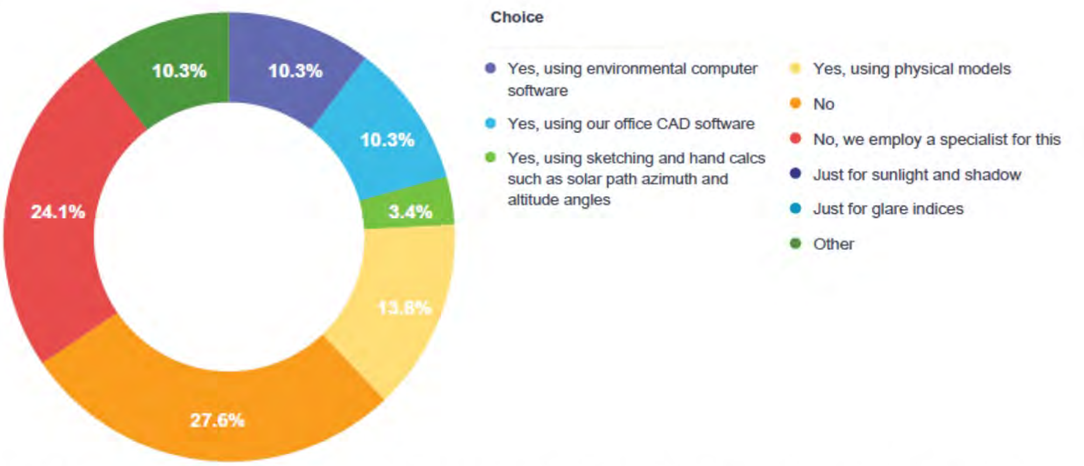


Q4: Do you design your buildings or interiors with daylight as a primary concern?



Q5: Have you ever carried out daylight evaluations, eg. how much daylight you will receive into your spaces?

When 'sunlight' evaluations were considered the engagement with this aspect was further diminished as less than half responding said they carried out their own sunlight evaluations. The answer to this question is so misaligned with the confirmed importance of daylighting in a building that the extended answers were required to also be analysed fully. This deeper investigation noted that longer written responses were confusing sunlight analysis with Daylight Factor and suggesting that there may be confusion with the terminology but also perhaps that the question was too ambiguous for non-lighting specialists.



Q6: Have you ever carried out sunlight or glare evaluations, eg. when and where you will receive sunlight into your spaces or the angle of the sun for solar shading design?

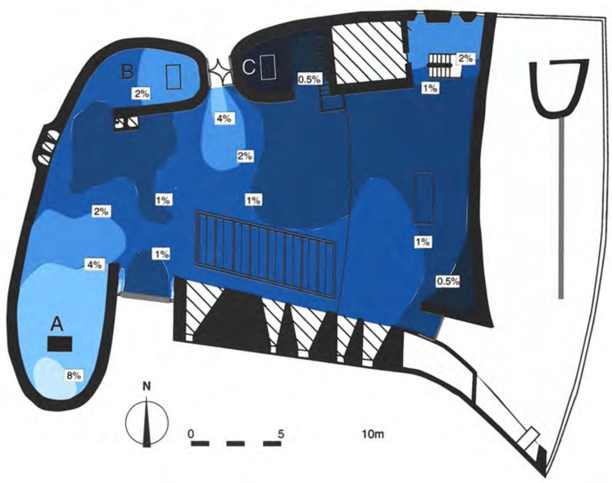
3.4.1 How well did participants respond to visual question types?

Many of the questions were created by introducing a series of visuals to view and respond to. Each visual example provided a different format and level of lighting information to ensure a fairly broad range of contemporary lighting representations/information outputs were tested. Responses to these visuals were requested as a series of qualitative descriptive written answers to these branched, open-ended questions. It was expected that through analysing these descriptions of the visuals some understanding of the common or diverse interpretations of architectural lighting from analogue and digital representations of lit spaces would emerge.

The questions were created as paired visuals; representations of the lighting of interior spaces. Each question displayed a simple visual showing one representation of lighting information. The following question of the pair added an additional layer of lighting information. The participants were asked to respond to each question in sequence and not to return to a previous question. This guidance was to ensure parity in the sequencing of responses and to guarantee responses were not affected by information gained in later or proceeding pair of questions.

The selected examples utilise plan views of an iconic architectural space; Le Corbusier's Notre Dame du Haut. This case study was selected for its notoriety and familiarity in architectural communities in Western Europe (the participant group were UK based) and, most importantly, the variation in daylighting conditions and ambiance in the space. It was expected that any architectural designers familiar with the work of Le Corbusier would, for example be able to identify the building by its unique plan form and elevational profile.

The visuals shown in the questionnaire therefore take the form of an illuminance contour diagram as an orthographic plan projection where contours provide points of equal illuminance.



Without reference to any other source, using a few lines of text, can you describe the daylighting of this space? You may choose to describe areas A, B and C. Are they light/dark? Do you think it would be possible to read in this space? Please state the lighting metric used if you know this? Please also name the building if you know this and if you have any experience of visiting it?

Figure 13 and 14 (Part B of question above) - Notre Dame du Haut Survey Daylight Factor Question – Shaded contour plan with numeric DF.

Image from (Fontoynont & European Commission. Directorate-General Xii, 1999)

This format of a plan with contour lines is representational of the varying daylight levels throughout the space as calculated on the working plane[1]. Rather than Illumination levels (Lux) being shown, the plan indicated Daylight Factor (DF)[2] numerical values, expressed as a percentage, a visual format used by many daylighting and environmental design software applications. As DF values are often prescribed as part of local authority planning and building control guidance (see Chapter 2), it was assumed that this would present as a familiar lighting metric to many spatial designers in the UK.

[1] The ‘working plane’ as defined in https://www.cibse.org
[2] Daylight factor as defined within https://www.cibse.org

3.4.2 Results of Numerical Daylight Factor Representations

Of the total respondents, only 10% were able to correctly describe the metric used as 'Daylight Factor' and/or most commonly, incorrectly used the term 'luminance' in their response. When asked to discuss the predicted lighting contrast in the space only two of the respondents identified with the numerical characteristics of the isolux diagram and were able to note ratios of 1:5 etc.

It was useful to compare the results of this visual type question defining Daylight Factor values in relation to 2 other questions set within an alternative section of the questionnaire. These questions asked for confirmation of any specific lighting metrics or units of measurement the participants used in their practice. Although more than 20% of respondents said they use or have used DF, it was apparent when analysing the results of the visual DF question above that only half of these participants understood the metric in practice. The second example used the same plan showing the same Daylight factor values but added a graded white to black monochromatic shading render between each contour relating to the DF values: high (white) to low (black).

3.4.3 Results of Daylight Factor and Shaded Contour Plan

In analysing the responses, it quickly became apparent that with this additional layer of information it was possible for participants to describe the numerical values appropriately. Significantly, using the combined rendered and numerical visual, 90% of the participants felt confident enough in their understanding to answer this question and 60% of these participants discussed the contrast using the numerical information given on the plan. These data highlight clearly that the visual format, including the shaded patterning helped significantly *in the translation of* the numerical DF information.

The second pair of questions were selected to show a virtual view of the same built space created using Sketch-up. For continuity the same building was chosen and the same main space visualised but in this scenario the format was a virtual representation of the space with shadows turned on and materials as defined by the limitations of the software's materials palette library.

3.4.4 Results of 3D VE Visual and Luminance Values

The same questions were asked and the results were considerably different. It was assumed that participants would at this point realise that the space they were considering was the same one as that in the previous questions but it is clear this was not the case. Participants described the space in terms of volume and only 5% of respondents wrote more than a couple of words describing the lighting. The second visual of the pair had luminance information added as measured on site at the time of the photo being. Luminance levels were measured with the use of Photolux app[3]. Many more participants responded to this visual and notably 30% discussed the lighting contrast. It was particularly interesting to note that the Sketch-up visual did not show as significant contrast values (to see by the eye) as the numerical values displayed and yet all the descriptions suggested that there was 'little contrast', or the space was 'evenly lit', even although the measured contrast was 1: 5 and were noted as such on the visual. It was apparent that although this numerical information had been added to the visual the actual numbers shown either weren't understood or the participants had an overriding bias to the visual scene shown rather than translation of the numerical results.

The final pair of questions aimed to define a descriptor of the lit ambiance of the space using a photographic visual of the interior. Again, for continuity, the same building was chosen and the same main space visualised but in this scenario the format was a simple colour photograph of the space.

3.4.5 Results of Visual Responses

All participants responded to this visual and responses used many verbs and adverbs to convey the lighting. When asked to describe the contrast in the space all attempted to discuss the contrast *in relation to* the architectural characteristics such as; "sharp light through the small piercing windows against the gloomy wall', 'tiny windows provide strong contrast', 'the dark areas are contrasted with the very bright clerestory'. The context of the lighting and its relationship to the built space was clearly helpful in providing an ambiance that could be visualised and described easily by the participant group. The second image of the pair used the same base photograph but added in

[3] https://www.photolux-luminance.com

luminance levels as measured on site at the time of the photo being taken. Luminance levels were measured with the use of Photolux app. With this added information 70% of participants chose to discuss the numerical contrast values alongside the text descriptors. The added layer of luminance values provided further information to discuss but was clearly understood as a metric in relation to the view of the interior space.

3.4.6 Summary

Findings suggested a strong link between the lack of understanding of lighting metrics in participants and the high percentage of practices using specialists to help with daylighting evaluations. It was interesting to note that DF and luminance contrast was not easily understood through the visual or numeric examples presented within the questions, yet the number of respondents discussing DF and contrast with clarity was considerably increased when a combined visual and numeric representation was presented.

3.5 Students' Survey Questionnaire

Data were collected using a questionnaire distributed to students within the two participating University groups. Ethical approval for the study was given by the Research Ethics Committee with informed consent from all subjects. The full questionnaire is located in the appendix for reference.

To explore the themes of pedagogic techniques the questions were created to reveal design background, daylighting knowledge (and the acknowledged source or methods used in gaining this knowledge) and the "chief concerns" of spatial design students "community of practice" in relation to daylighting design within spatial design.

This questionnaire was given significant value as it was expected that the themes emerging from the findings would feed into the research design and help determine appropriate scenarios for exploration. Additionally, with pedagogic practice under scrutiny and investigation through questions to student participants regarding design learning, it was hoped that this exposure of gaps and successes in learning might benefit future research into design pedagogy.

One questionnaire was created and the student participant group were expected to fill this in at two points in the research study; during workshop time in week 1 and then again in week 8. This allowed a comparison of answers from the start of the study to the end, encouraging participant reflection and information on any answers where opinions or knowledge had shifted.

3.5.1 Analysis and results of the Students' Survey Questionnaire

The Students' Survey was set as a series of open-ended questions (text-free comments) and were analysed using a simple ground-up thematic analysis (Braun and Clarke, 2006) to identify common themes. The answers were collected and categorised into themes of responses for each question. It became apparent that many participant comments were pertinent to more than one theme such as daylighting 'language' being difficult to comprehend causing, in turn, a lack of understanding of daylighting 'metrics' relating in particular to a 'lack of confidence' in the use of daylighting in spatial design projects and a necessity to use 'intuition' as a result. The predominant response was that daylighting was of great value to the student spatial designer but they were unclear how to work with it or use it within a spatial design.

In week 1 the lighting terminology question responses were limited. Almost no students (2 no.) were able to define 'illuminance' and less still 'luminance' (1no.). The responses in week 8 (further to the workshops demonstrating some better clarity towards lighting terminology with almost half able to describe both of these terms.

Further, in week 1, question 1, 80% of respondents said they did not feel confident working with daylight in their spatial design projects in 2015-16 and 70% in 2016-17. The main reasons given for this were that they "not had the chance to work with/talk about it much".

In summary, it became clear that the students taking part in the questionnaires in week 1 demonstrated limited experience of designing with daylight but thought it was important. Additionally, they had very little understanding of the terminology associated with the quantitative aspect of daylighting design or words or visuals to describe.

3.6 Discussion of Pilot Study Questionnaires

These pilot studies sought to provide a basis for the research questions. With empirical evidence provoking tentative definitions of design motivations and new understanding with regard to daylighting from analysis of the responses to the 2 questionnaires the research proposal was formed.

The responses within the questionnaires were evaluated within the two categories of 'spatial design practitioner' participant and 'design student' participant. However, the data collected within this section of the research project identified that all participants of the questionnaires advocated for the introduction and use of daylight within inhabited architectural spaces. All participants identified a significant importance or "value" for the inclusion of daylight in buildings. Many attributing this to daylight creating ambient "atmosphere" and contributing to "natural" environments indoors with authentic "connections to the outdoors". This indicates a natural human response to daylight and underlines our appreciation for connections to our external environment through daylight. These early exploratory studies therefore revealed that the spatial design "Communities of Practice" taking part in these pilot study questionnaires loosely shared the value of daylight as, "creating a sense of place" through definition of time and locality through its "transient nature" and "sculptural, natural qualities touching architectural space".

These results clearly identified the anomaly anticipated at the beginning of the research project through my experience of architectural design and teaching practice. The apparently shared ethical design "value" apportioned to daylighting within the community of architectural designers is not matched by engagement with daylight in architectural design practice and study. These early findings suggested significant relationships between shifting design priorities yet the underlying importance of daylighting in spatial design, the level of involvement the designer had in the project to the lack of understanding with regard to daylighting metrics and measures necessitating the use of intuition in making design decisions about daylighting. These incongruous relationships therefore provided the challenge for this research study through the need for exploration of these disparities; a designers' philosophical value of daylighting, defined as their epistemological perspective undermined by the complex challenges of engaging with daylight. What was causing this lack of engagement with daylighting within spatial design?

From these early pilot studies, it was evident that qualitative ontologies of daylight were dominant within the participant group studied. Findings from questionnaire responses clarified participants' ontological perspectives for daylight as a qualitative design tool and highlighted a lack of knowledge and interpretation of numeric, quantitative approaches and visualisations. Responses to Practitioners' Survey, portrayed daylight as a predominantly atmospheric element *added into* architectural interiors to provide the designer's desired qualitative ambiance. Analysis of findings revealed that daylight was most often represented through architectural visual representations and these were commonly the architectural designer's only notable display of engagement with daylighting in their design projects.

Findings revealed distinct ontological and epistemic perspectives for daylighting within practising spatial designers' "communities of practice" (Wenger, 1998). They approached daylighting as a qualitative addition to architectural space and place-making and apportioned significant value to atmospheric creation and visualisation of this through daylight's connection with architectural space; materials, spatial volume and shadow. This indicated a basic ontological approach to architectural design through the knowledge of how architectural components relate to each other.

Responses to descriptive text and photographic images were lengthy and discursive. Responses to quantitative questions were limited in length or missed out entirely. Only 10% were able to answer the question regarding Daylight Factor with any demonstration of understanding although many said they used this metric during their design work. This highlighted that the participants had varied pockets of useful daylighting knowledge but this had remained rather unconnected and therefore ineffectual in design practice. It was therefore necessary to carry out further research into this area to clarify why this qualitative epistemology for daylighting prevailed over other quantitative measures for daylight and why there was this clear lack of engagement with quantitative approaches. This was also important to ensure any new approaches engaging with quantitative daylighting measures might be successfully trialled.

However, beyond an ambition for a visual expression of daylighting in architectural space, the Practitioners' Survey results highlighted that most participants were challenged by engaging with the technical quantitative understanding of daylighting in great depth. A motivation to understand daylight's behaviour, hidden behind the visual realm, was not apparent in the responses. This participant group assigned little value to understanding the underlying relationships between a daylit space as visualised (virtually or in reality) and the associated numeric lighting analysis of that same space. Additionally, it could be proposed that the format within which the daylighting was presented in the questions; visual plans, isolux contour diagrams, photographic images, defined the length of response given by the participant. It is possible therefore to suggest that the associated 'value' attributed to this type of daylighting information by the designer was evident in their response.

Further, it can be proposed that the format used to present the daylighting design directly influences the success of the translation of and use of the daylighting information. This was understood to be an important insight as the format of the research study investigations could have a significant impact on the participants' engagement with daylighting and the associated tasks and scenarios explored. Participants who were unable to answer any of the 'technical' questions displayed a gap in their knowledge that suggests a problematic relationship with carrying out quantitative analysis. Through a lack of engagement with this quantitative ontology for daylight their epistemic understanding of the lighting principles, knowing what causes daylight to behave in a certain way, was and would likely remain extremely limited. It could be concluded that this finding highlighted that a singular or 'mono' ontology for daylight existed in this participant group.

As the primary respondents to the questionnaire were spatial designers (86%), the resulting findings of this study in relation to ontological or epistemological perspectives of the other participant groups taking part in the study was rather limited as the numbers were too few to draw substantial conclusions from. However, findings did highlight that all those participants identifying themselves as environmental designers or researchers (3% of total respondents) were able to successfully explain the quantitative lighting visuals and also provide written descriptors for the qualitative daylit scene visuals, though not all demonstrated a consistently correct use of terminology.

The language these participants used in the verbal descriptors was significantly more 'technical' in nature, such as the inclusion of descriptors of metric units of illuminance,

luminance, luminance contrast etc. This correlated with findings from the pilot study review of design versus daylighting/environmental texts and the corresponding use of technical terminology (described earlier in this chapter). It is now evident that in all instances; whether originating from questionnaire responses or the design or daylighting text books, that the amount of ‘technical’ lighting terminology used indicates the ontological perspective of daylighting driving the epistemic perspective of the author, either towards qualitative or quantitative values but rarely equally balanced.

It was therefore significant to find that through questionnaire responses it was possible to identify a participant’s approach to and reading of the daylighting of an architectural space. This was understood to be determined by his or her own epistemological understanding of daylight, influenced by their ontological knowledge base and the community of practice within which they align themselves.

This was shown to range from a limited mono-ontological perspective for daylight as shown by the majority of architectural designer participants, to acceptance of multiple and equally valid ontologies for daylight as demonstrated by the environmental design specialists who aligned with both qualitative and quantitative ontologies. Critically, findings from the Students’ Survey demonstrated that ontological perspectives can influence epistemic understanding and the subsequent value daylighting is afforded by the designer in their spatial design projects. Those respondents who were able to discuss with some understanding or those that expressed a wish to understand, ‘technical’ daylighting information described ontologies for daylight that were fluid and willing to adapt to suit future demands. This attitude towards daylight was not evidenced in the Practitioners’ Survey.

The literature review confirms that this mono-ontological perspective for daylight is not new to architectural design. The use of lighting metrics, lighting as a quantitative measure, has clearly been side-lined within architectural communities since their introduction in the 1960s in favour of alternative aesthetic, functional or environmental aspirations of spatial design. However, these historical boundaries with defined mono-ontological attitudes towards daylighting design cannot continue if we are to progress spatial design thinking for the future. Future trends demand increasing engagement with quantitative daylight ontologies through daylight metrics and verification to respond to environmental concerns both in energy demands and human health and well-being.

This study proposes that spatial designers prioritising the atmospheric, qualitative representation of daylight engage only with a limited perspective and fall short of engagement with and understanding of other key design parameters of daylighting. This lack of engagement and motivation to 'see' an epistemic perspective of light as simply quantifiable inhibits clarity and confidence in daylighting design strategies and will increasingly limit successful, ambitious integration of daylight into architectural design projects.

Results of Practitioners' Survey questions highlighted that practicing spatial designers often consider qualitative daylight in their architectural design aspirations. However, daylight analysis is not seen as an iterative design process for daylighting but a final verification. It is therefore important to note that results from the questionnaires define numerical, quantitative design processes as daylight 'analysis', rather than' iterative design process' and as such quantitative daylight analysis is left to design detail stage or passed to others in the design team to calculate and verify (see results earlier in this chapter). It is only at this late stage the spatial design is numerically verified for compliance with energy and daylight regulations and, findings suggest, almost never in relation to the atmospheric (architectural) visual aspirations of the designer. This is the point at which the spatial designer may lose control of the daylighting concepts as numerical values are misunderstood or considered unrelated to the atmospheric spatial aspirations.

It is hypothesised that the spatial designer, with clarity in his or her epistemology of daylighting, will be able to, at this stage, successfully address any numeric imbalances relating to material selection, glazing specification or spatial proportions. As such, they will be able to fully control the daylighting concept through full scheme design and detail stage. However, this continuous, integrated, approach was not recorded in any questionnaire responses from spatial designers, suggesting a lack of clarity of daylight understanding beyond early architectural visuals or concepts.

It was found that daylight 'analysis 'tools were used for simply this purpose, last-minute analysis of a project already designed. They were not being used as daylighting design tools.

Two reasons were found for this:

i) Respondents to the Practitioners' Survey noted that daylighting analysis tools (that they engaged with – digital in most cases) needed 3D models for import. This model could not therefore be a first loose sketch or model but needed other information already in place such as wall finishes, volumetric decisions etc. The tool was therefore fitting in to a latter part of the design process only.

ii) Respondents to the Practitioners' Survey found that daylight analysis tools that were not digital seemed to "lack any real authority" and the terminology was "outdated". This implies that the designers were not understanding the use, scope and method for using the hand calculation/graphical methods, and, as they were older, traditional methods it was assumed that the language used was archaic.

Critically, this early research identified a key finding that demanded consideration when assessing current daylighting design "tools". The questionnaire results also highlighted that many daylight analysis tools were considered too time consuming, in operation and training requirements or too complex to use. These findings imply a new epistemological approach to daylighting design is necessary alongside new tools to assist in this if both quantitative and qualitative ontologies for daylight are to be addressed within the conceptual design stage (or stage at which first visuals and models are to be produced).

3.7 Conclusions

These findings from the questionnaires, although limited due to the participant groups locality (UK based) and number of participants, highlighted points worth investigating further. Respondents showed little awareness of lighting metrics, their numerical relationships and the technical terminology associated with daylighting. It must be presumed that either these architectural designers do not have a need for this knowledge or they are passing these aspects of the design on to another. Were the numeric values simply not understood? Research has shown that our understanding of lit ambiance cannot easily be equated to photometric values (Boyce & Smet, 2014). As daylighting metrics are derived from schema that are fundamentally mathematical constructions, not physical luminous quantities, (P. Tregenza & Mardaljevic, 2018), it can be challenging to predict the temporal, context specific phenomenon of daylighting ambiance in an interior space.

To add to these highlighted intrinsic difficulties in working with daylighting and its associated metrics, initial insights from the Practitioners' Survey exposed an apparent de-valuing of daylighting design tools in professional and educational design studios. With existing daylighting tools being used very little how could this be explored, validated and remediation proposed? As a continuation of this research study it was chosen to explore the reasons for this apparent lack of engagement with daylighting design in the field of spatial design. It is clearly understood by all research participants to be a very important part of a building design yet so far has received very little attention.

The data emerging from analysis of these questionnaires and textbook/journal studies generated the first themes for exploration in pilot study workshops. Three main categories for these findings were created to reflect the themes emerging from the results and used to begin coding the significant issues captured:

i) Architectural daylighting as understood through different architectural formats: visuals, text, numeric

ii) Daylighting calculations, metrics and their 'language' and 'value' within the field of spatial design

iii) Integration of daylight ontologies in design pedagogy, influencing CoPs, thereby influencing design practice

Further research explorations sought to explain and challenge this mismatch. As qualitative and quantitative ontologies become increasingly aligned with mono-ontological daylighting concepts, the necessity for new *translation* tools or methods to address this imbalance becomes critical for the survival of daylighting, the elusive "thingness" (Holl, 2000) of light within the buildings we inhabit.

Chapter 4 Methodology

4.1 Introduction to methodological approach

Chapter 4 seeks to explain the methodological approaches chosen for the research. The hypothesis of this research was initially identified from experience in design practice and teaching lighting design, interior design and architecture. In these contexts it was observed that many spatial designers' engagement with daylighting in design projects was limited and for some this indicted a lack of confidence in the use of daylight in their design proposals. This limited input from designers did not correspond to the level of value they attributed to daylighting in architectural space, (evident in the findings of the Practitioners' Survey in Chapter 3). The missed opportunities to work with daylighting were apparent. Without the consideration of daylighting, the possibilities of including proven health benefits, reduced energy consumption and valuable lighting quality into the generation of architectural proposals are known to be greatly reduced.

In order to investigate this issue further, a hypothesis was proposed stating that it was possible to identify suitable design tools, perhaps defined as methods, for use in design studio environments to positively improve and enhance this relationship between architectural designer and daylight. The aim of this research was therefore to discover appropriate methods to increase spatial designers' awareness and engagement with daylighting in contemporary spatial design and benefit future users of the designed spaces. It was considered relevant to approach this investigation through daylighting design pedagogy. This would allow insights into a designer's formation of their daylighting epistemology, and test practical ways to adjust and develop existing approaches to learning, that are, in turn, realised in future spatial design practice.

This chapter aims to define the research approaches proposed, and the rationale for these within this particular study context. Findings from the literature review (Chapter 2) and Pilot Study Questionnaires (Chapter 3), identified the nature of daylight in spatial design contexts as; aesthetically important, numerically complex and low on the priority list of spatial design agendas. Further it was noted that the increasing complexity of quantitative daylighting analysis has proved difficult for spatial designers to engage with in professional practice.

The research study builds on the recognisably disparate issues within daylighting and spatial design outlined in Chapter 2. It aims to discover connections to bridge these differing paradigms through investigative design student workshops. The methodology is shaped by published papers outlining example design teaching methods that correlate with holistic learning of the architectural environment, thereby not categorising daylighting in architecture as an art or a science but allowing an exploration of both quantitative and qualitative domains to find new terrain and learning approaches. It advocates that the relationships identified may positively provide a new approach for daylighting pedagogy. For those starting out in spatial design education or practice such as novice students and professionals, the proposed methodologies and aligned methods aim to ensure daylighting knowledge and cognitive design skillsets (design competencies) provide a closer match to current and future demands of architectural daylighting design, allowing readjustment as the field develops.

The research methodology proposed seeks to establish effective engagement with daylighting design pedagogy and is therefore structured as an investigation into design teaching practice. This study considers the methodological rationale for my own and of others in the specific and related fields including educationalists with overlapping and related interests, with experience of exploring pedagogical demands with similar challenges.

Using these teaching pedagogies as a catalyst, Chapter 4 of the research study proposes a series of themed theoretical constructs that are known to inform pedagogical methodologies. These themes have been selected from the wider realm of epistemologies of learning and the focussed understanding of methodologies underpinning design learning in particular.

This chapter includes an introduction to design methodologies insofar as it provides information on the current status of design pedagogies used in the wider subject domain. This seeks to unravel the background for the pedagogies evident in current design education and the move, over the last two decades, to develop learning strategies around "student-centred teaching and learning approach" (Samarji &

Hooley, 2015), defining threshold concepts within disciplines (Cousin, 2006), focusing more on “what the student does” rather than on “what the student is” (Biggs, 2011). It is proposed that the design knowledge a designer has and the values they assign to it through their epistemological perspectives can be analysed through the expression of their response to design briefs, creation of representation of design ideas and representation of spatial ambience through their design processes.therefore the final part of this chapter concludes with a discussion of design ontologies and epistemologies, their influence on the way a designer thinks and how this can be altered through pedagogical approach.

4.2 Design Knowledge Cognition and Framing within Methodology

Methodologies were sought to complement and challenge this search for learning tools and provide insights into architectural designers’ processes, design knowledge and the relationships of these aspects with daylighting design.

Design knowledge has been defined by leading pedagogical and design researchers with the majority of discussion centred around application of design knowledge. This also includes relevant transference and reflection of this knowledge into new contexts [Mewburn, 2012, Lost in translation: Reconsidering reflective practice and design studio pedagogy], (Schon & Desanctis, 1986) and the challenge to explore designers’ tacit knowledge, (Cross, 2011), (Gero & Maher, 1992). In this particular research context, design knowledge is framed and investigated through the application of an individual’s background knowledge informing the process of designing with daylight when task stimuli and tools are provided. This conversational data sought to allow analysis of the expression of this knowledge through recorded reflection-in-action (Schon & Desanctis, 1986) interactions and exposure of intuitive behaviour through design “moves” whilst working through the given tasks.

Further to analysis of empirical research of design protocols used in Schön’s architectural tutoring practice during the 1980s, it is understood his methods demonstrated a methodological theory of ‘reflective practice in action.’ This was informed by ethnographic methodologies that investigated cognitive processes of design teachers and students through explicit means, design critiques and discussions (Schon & Desanctis, 1986). His methodology identified with architectural practice being unique to other professions as it demanded thinking that assumed, uncertainty and complexity and benefitted little from “technical rationality” available through “scientific theory and technique”(Schon & Desanctis, 1986). With this methodology framing his analysis he determined methods of protocol analysis through the definition and linking of designers’ thoughts and “moves” (Schon & Desanctis, 1986). His understanding of the reflective cognitive processes in design aligned with his aspiration to find solutions to design problems through flexible and strategic methods. He understood this as emerging as a conversation with self, working intuitively or explicitly with others, necessary in a dynamic, ever-changing world environment. A first design idea could not and should not be finite as its authenticity evolved through these conversations and protocols.

Schon’s ideas can be understood as giving value to design processes and educational methods through teacher/pupil review sessions that had previously been difficult to show their worth in comparison to other subjects. Although many educationalists now discuss his findings as imbalanced, and lacking “authenticity”, due to his dominant role as ‘instructor’ and student as “passive learners” in the design activities he analysed [Mewburn, 2012, Lost in translation: Reconsidering reflective practice and design studio pedagogy], (Webster, 2005), (Webster, 2004), (Dutton, 1987), the design studio is a challenging environment for empirical discovery and he developed new insights into design processes through these first attempts of protocol analysis.

It is evident that Schon’s methodology can still have value in the realm of design process research even if the pedagogies used are now questioned in contemporary design teaching. His investigations into design protocols highlighted designers’ insightful responses to design situations through explicit methods. These investigation methods provided verbal data that allowed analysis and observation of new “understandings” and “appreciations” the designer made through their sequence of design “moves”, particularly when the “consequences were not as intended” (Schon & Desanctis, 1986) and the design idea needed re-visiting.

The cognitive process of reflection-in-action through his, ‘think aloud” method identified by Schon has been further demonstrated and tested by designers in alternative design studio settings: through conversations between design colleagues in studios [Farías, 2015, Epistemic Dissonance: Reconfiguring Valuation in Architectural Practice], considering protocol analysis of ‘desk crits’ and ‘reviews’ in lighting design education in particular [Hegde-Niezgoda, 1991, Assessment of perceptions of design educators and professionals regarding lighting concepts for design education], physical light modelling techniques with design students to explore artificial lighting [Andersen, 2011, Espace & Lumière: Unité d'Enseignement M | Space & Light: Teaching Unit M], and in other areas more broadly through product designers' process of a given brief through drawing techniques (Cross, 2011) and (Lawson, 2006).

Protocol analysis is described as "a rigorous methdology for eliciting verbal reports of thought sequences as a valid source of data on thinking" [Ericsson, 1993, Protocol analysis : verbal reports as data]. Within the context of this study it was expected that protocol analysis would assist in clarifying, not new ideas per se, but new approaches to a design intent or concept through verbal analysis. As this study's ambition was to find how learning of design concepts was encouraged or hindered by the tasks set, the protocol analysis was expected to reveal insights into this particular area of interest. Using protocol analysis, it was assumed that it would be possible to not only understand how the process of undertaking design tasks but also allow other, behavioural insights, to emerge.

4.3 Methodologies for design process explorations

Cross considers the work of a designer as an "exploration process" with the most creative interpreting the design brief as a "starting point for a journey of exploration" (Cross, 2011). This interpretation can be understood as a first response to a design situation that demands engagement with the design idea through the given stimulus. In Cross's example this is the design brief. The design brief, as central to the process, invites exploration of new territories and landscapes to reach the unknown, rather than the application of "another example of the already familiar" (Cross, 2011). It often encourages a "holistic review of the problem encapsulated in the goal" (Cross, 2011), p. 75. Therefore for this study, it was understood to be beneficial to the use of a brief to invite engagement with tasks. This would require engagement through processes that would be unfamiliar, but allow for some familiarity in the new scenario, encouraging new, perhaps previously unconsidered explorations.

Further, it was also expected that the workshop design brief would present some guidance on suitable actions or approaches for participants through development or realisation of specific daylighting tasks. The brief could there be used to provide security through suggested boundaries (size of model, types of materials, location of task) yet limitless opportunities (daylighting effect, spatial relationships, material textures). This highlights the need to allow for creative diversity in the tasks set, to ensure the brief does not stifle opportunities for learning.

However, locating when and how learning is occuring whilst participants undertake design tasks is difficult to analyse as thought is by its nature, is difficult to research empirically. Participants' responses to stimuli (such as the design brief, a design object or a particular experimental set-up) necessitate some understanding of a designer's epistemology and the process of augmentation of this as learning occurs. Therefore, 'implicit' learning, that promotes knowledge that is acquired incidentally as the task is carried out is particularly relevant to analyse within this study.

Arthur Reber's (1967) study proposed 'implicit learning' as a "form of learning that occurs in the absence of an intention to learn and that results in a form of knowledge that is expressed in performance, but is difficult to verbalise and not accessible to consciousness". It was therefore important to allow the protocol analysis to include initial discussions of the brief between participants to clarify understanding and record any explicit comments then for first steps to be analysed in comparison to final actions and verbal discussions to allow for analysis of any inplicit learning.

Cross argues that design process is not simply a matter of recognising a pre-existing pattern in the data, but of creating a pattern that re-formulates the problem and suggests directions towards a new, creative and often distinctive solution. Designers are most commonly identified with their "tacit" knowledge being inherently possessed, developed through "experience" or "past experience from inappropriate responses" (Cross, 2011). As this research study sought to understand participants' understanding of daylight and their tacit knowledge in order to develop and advance any basic skills, protocol analysis of responses to a design brief through didactic tasks was understood to be appropriate and necessary.

4.4 How can we define appropriate methodologies for the novice designer?

> *In Piaget's view (1955), cognitive development, which he called development of intelligence, is based upon assimilation of newly experienced phenomena in already existing cognitive schemata and accommodation of those schemata in cases where the new information does not match the existing schemata.*
>
> *(Sigmund & Thomas, 2009), p. 145.*

Cognitive scientists have found that experts performing routine tasks work forward from the present situation: they recognise what the problem situation is; they know what to do with the new phenomena or situation and do it, without needing to formulate a plan. Novices, who lack task-specific situation–action associations, explore and learn from their mistakes. They reason backward, from what they want to how they can get it, applying general problem-solving strategies to the facts that they know (Flanagan, Eckert, & Clarkson, 2007). Ahmed et al. (2003) observed that novice engineers jump straight to a solution, which they implement quickly, and which often fails, leading to iteration.

Flanagan et al (2007) note that experienced designers spend more time formulating the problem and decomposing the problem into manageable sub-problems. Further, experienced designers think more about their solutions: they are able to better assess whether a solution is likely to succeed and only implement such solutions (Ahmed et al., 2003). Cross (2004) highlights that experts and novices differ in their approach to solution space evaluation: expert solutions are achieved through top-down, breadth-first searches whereas novices use in-depth first searches (exploring single solutions in depth).

> *[Expert designers'] approach is strategic not tactical…an important feature of their strategy is parallel working – keeping design activity going at many levels simultaneously.*
>
> *(Cross, 2011), p75.*

Experts are also able to consider the wider context for the potential solution, picking those that are likely to result in fewer problems downstream. This is one of the main reasons why novice's solutions can lead to iterations: they do not consider the implications widely enough.

In summary, it is therefore of value to this research study to be informed of these patterns of behaviour and create scenarios that can be handled in an iterative way, by novice designers, who demonstrate different problem-solving strategies to those of spatial designers in professional practice. Any design brief for a workshop should invite approaches and use methods that can be deconstructed (are demountable), and flexible, to align with these design strategies that novices are known to use. It is proposed that assembling components to model (physically or virtually) complements these iterative processes providing a platform for this "designerly way" (Cross, 2011) of thinking. Further, to encourage novice designers to work on many levels of a daylighting design, the methodologies used would need to allow different levels of complexity to challenge each designer, beyond the processes of a "junior" (Kirschner, 1992) spatial designer, but with an aim to keep progressing their skills towards an 'expert's synthesized strategies.

4.5 Methodologies for researching 'Design thinking'

Cross (Cross, 2011) identifies three types of "design thinking" that support designers' investigations into design problems which in this context, can be defined as design methodologies:

1) a "systems approach",

2) a distinctive "framing" of the design problem

3) "designing from first principles".

These three key methodologies highlight the varied, personal and distinctive approaches designers have when considering a new design scenario and for most, a sequential process.

Although the methodologies outlined in Cross's studies are approached from investigations into formulating new design ideas, the constructs of the idea formation are significant and useful as they suggest how the application of a "first principle"

(Cross, 2011) or “threshold concept” (Cousin, 2006), can be integrated into the design process.

Consequently, it was proposed that from these methodologies we can define new constructs for integration of a new spatial design threshold concept, with a methodological process as follows: 1) “framing” of the design problem (through the workshop brief) from which the “first principle” is selected, 2) first principle is introduced/applied (within a workshop task), 3) consideration of the integrated system that forms and shapes the character or behaviour of design when the “first principle” is applied (“structural” understanding (Gero & Kannengiesser, 2004), a holistic proposal. It is therefore valuable to investigate the “design thinking” structures behind these methodologies further to reveal practical methods and tools that permit this approach.

Maccoby in “The Innovative Mind at Work” in (Cross, 2011) notes that a “systems approach” is apparent in designers that “see things in terms of how they relate to each other in producing a result”. This finding provides insights into the approach taken by designers who successfully seek and achieve holistic solutions. Although Maccoby has created these definitions for the field of product and industrial design engineering the terms are no less valid in spatial design where various competing and conflicting priorities must work together to create a realised architectural space or “total systems approach”. This “whole process” is defined within his example using automotive design, through the design of all the systems working together to fit within a wider context of “winning the race” (Maccoby, p 76). This methdology can also be applied to spatial design solutions by providing the user of the space an architectural experience whilst giving the space relevance in its wider social, environmental, political and urban context.

This “systems approach” is frequently used within product design and can be evidenced too in spatial design as we see legislation demanding more and more a “systems approach” to construction projects in the built environment where Building Information Modelling is required (Natephra, Motamedi, Fukuda, & Yabuki, 2017). Many spatial designers seek to avoid this “system approach”, seen as detrimental to or at the expanse of good quality design, through design optimisation goals or formulaic design (Weng, Ramallo-González, & Coley, 2015). However, on a theoretical level, this systems approach is a skill all designers use on a daily basis to integrate all the elemental factors (form, structure, energy use, materials and colour) to suit design priorities within every spatial design project.

Without the ability to think in this way (as an expert designer), working on the varying factors of complexity at once even proposing the next move or appropriate action can become challenging. Through studies with design students and professional designers, Jansson and Smith (1991) found that designers can be trapped by the characteristics of a possible solution that has already been developed, or by existing precedents.

In the domain of product design the introduction of heuristics into this process can be helpful for the designer in the generation of new ideas and there has been substantial research into this domain [Yilmaz, 2010, Cognitive heuristics in design: Instructional strategies to increase creativity in idea generation], (Studer, Yilmaz, Daly, & Seifert, 2016) and (Restrepo, Ríos-Zapata, Mejía-Gutiérrez, Nadeau, & Pailhès, 2018). For the novice designer, heuristics can assist by limiting the choices of actions to those that are most appropriate for the given context, through a "systems approach". This has been shown to ensure that the novice designer does not become lost in the complexity of decision making and endless unsuccessful iterations. This has rarely, if ever, been investigated empirically within the field of daylighting in spatial design. It was therefore seen to be an opportunity to begin the recording of distinctive heuristics for the field of daylighting design through considered approaches and actions.

The second approach of framing the design problem addresses the notion that the approach a designer takes to a design scenario is founded in the exploration of the scenario from a "particular perspective". Cross identifies that this framing process is "strongly influenced" by a designer's personal motivations. Cross also introduces the idea of "perceptive insight" through the interview of the designer Kenneth Grange who described himself as working initially with "first principles" but was also aware of a "perceptive insight", (Cross, 2011), p.70, informing his design decisions as he worked through his ideas. This "perceptive insight" gives what might otherwise be referred to as design direction, focus and sudden clarity. This also relates to experience as previous perceptive insights are known to inform our current understanding and design position.

It is important to associate the idea of these personal motivations in relation to design pedagogy. As discussed in Chapter 2 of this study, we are aware that design motivations are largely influenced by a designer's experiences; through the ontologies of design they have encountered in their education and the epistemological perspectives of the Community of Practice to which they align themselves with. The concept of epistemological design perspectives is discussed in a further section of this chapter and explored in relation to pedagogical approaches defining qualitative or quantitative ontological perspectives.

The third approach Cross (2011) p.76, considers a further key factor in the design process is that of a reliance on "first principles". This is further discussed in the next section of this chapter as an alignment with "threshold concepts" (Cousin, 2006), defined as distinct concepts for daylighting design. However, they are discussed briefly here to acknowledge that these "first principles" are part of, and integrated with, the other two methodologies included here, assisting the "framing" of the context of the design scenario and ultimately become a significant part of the "systems approach" to the design proposal.

These valuable themes of inquiry were identified as appropriate to this research question. They sought to challenge how designers engaged with design problems in studio settings, what motivated them in their design response and how they applied the specialist concepts of their discipline, or "first principles" (Cross, 2011). Although the processes of design cognition may be expressed explicitly in design team meetings and professional studio scenarios this reflection-in-action can also be expressed through "tacit" means as the designer develops first ideas on paper individually working with and reflecting on these concepts expressed through the chosen media and haptic, heuristic interventions. The nature of "tacit" perception recognises an informal understanding we have of our world from a particular context.

This phenomenon can relate to our naturally lit environment and our understanding of daylight within it without undertaking any specialist design training. We all create an unconscious library of understanding built upon our life experiences and spatial explorations. Tacit knowledge was first introduced by Polanyi (1958) and many researchers since have investigated the phenomenon in multiple ways including Collins (2010) who has categorized the phenomenon in the sphere of education. The relationships he suggests within these contexts consider the student as an individual, as part of a social grouping and as a member of a society in particular contexts. It is apparent therefore that a designer's CoP may shape, hinder or develop this tacit knowledge.

Sayed et al [, 2010, Discursive design thinking: The role of explicit knowledge in creative architectural design reasoning] p. 211, comment that this hidden tacit knowledge cannot be relied upon to develop understanding of design processes as "the role of explicit architectural knowledge is fundamental" to develop the problem-solving techniques required in spatial design. Further, they advocate that,

> *E]xplicit knowledge can prove to be more efficient than implicit knowledge in raising the productivity of design behaviour in architecture and enhancing design solutions.*
>
> *Sayed et al [, 2010, Discursive design thinking: The role of explicit knowledge in creative architectural design reasoning] p. 211.*

The technique of explicit "think aloud" protocol analysis has been used to acquire this otherwise hidden design knowledge and associations of the designer [Schon, 1986, The Reflective Practitioner: How Professionals Think in Action;Al-Sayed, 2010, Discursive design thinking: The role of explicit knowledge in creative architectural design reasoning]. Making explicit this implicit knowledge of not just the creative act of architectural design, but the social constructions, associations between form and function and the "knowledge of other disciplines that intersect" with spatial design, allows for insights and analysis into a designer's epistemological perspective.

Protocol analysis was therefore understood to be an appropriate choice for this research study. However, rather than have a single designer describe their thinking as they were drawing a design or have them retrospectively comment on a design session, the chosen direction for this study necessitated insights into novice designers exploring new daylighting design principles.

Therefore it was decided that a better approach for this study was to record conversation of the tasks (as group work) *as they progressed*. It was expected that this method of recording group tasks for daylighting would provide insights into the frequency and purpose of "moves" novice designers make when working with daylighting through a set of workshop briefs in a discursive setting (encouraging explicit conversation).

> *Given that design consists of individuals working together to conceive and create objects [in this case - spaces], in relation to their imaginings of how other humans may behave when using these objects [spaces], it is apt that [spatial] design be examined within a social psychological framework.*
>
> *(Oak, 2011), p. 212.*

Conversation Analysis (CA) (Oak, 2011), is understood to assist in the understanding of how a designer approaches a task, but also, "how designers comprehend and negotiate both their own, and others', perceptions as they work" p. 211. CA was therefore used to review the "think aloud" data sets and provide insights into the cognitive approaches of a novice designer when developing daylighting ideas in collaboration with others. Excerpts from these recorded workshop conversations are discussed in Chapters 6 and 7.

4.6 How can we understand of ontology and epistemology in pedagogical contexts?

The study of epistemology is an examination of how we make knowledge (Dillon & Wals, 2006). We can determine what is understood to be this knowledge through identifying and examining its characteristics and resulting behaviours in people. With a pedagogical lens for this research study the following definition for an epistemological perspective for daylight is proposed:

- We can identify distinguishing characteristics of knowledge in daylighting design from research of current agendas in the domain and employ a focussed consideration of threshold concepts.
- We can examine how learners use this distinguishing daylighting knowledge, what meaning it has for them and how this knowledge subsequently impacts upon their behaviour.

We understand that a learner's ontological perspective informs their epistemology of design as ontology is concerned with the nature of social reality; the kind of things that exist, the conditions of their existence and the relationships between these things (Dillon & Wals, 2006) and (Ramey & Grubb, 2009).

Therefore, an understanding of the approach to learning is necessary for this study to ensure epistemological concerns are addressed. Constructivism has emerged over the past few decades as a powerful model for explaining how knowledge is produced and is proposed to be a relevant approach for this research study. Constructivist methodology emphasises, “interpretation, multiplicity, context, depth, and local knowledge” (Ramey & Grubb, 2009) p. 80. Knowledge, according to constructivism, does not exist in a state awaiting discovery but is constructed by humans through value laden interactions with the world (Gordon, 2009) pp. 39-58.

These are important issues to consider as this research study develops and analysis is carried out, as Dillon & Wals (2006) criticise, not all researchers pay sufficient attention to the epistemological, and indeed ontological, aspects of the research process, which others regard as essential to elucidate. This is important to recognise because it influences the relationship between researcher and participant – whether participants are viewed as active contributors or subjects to be studied.

> *Ontologies are structured conceptualizations of a domain in terms of a set of entities in that domain and their relationships.*
>
> *(Gero & Kannengiesser, 2004)*

When discussing ontologies for daylighting it becomes clear that ontological perspectives relate to how daylighting is used, observed and understood. Clarity in its structural connections to spatial design elements is also relevant. These understandings in turn help create the epistemological approach.

Epistemology influences the way in which the quality of research methods is demonstrated – the types of action undertaken to ensure data collection and analysis is appropriate and aligned. Third, epistemology influences the manner in which the researcher conceptualises, interprets and communicates their findings. The researcher’s epistemological stance is therefore foundational to the inquiry and will influence other aspects of the research process, more than be influenced itself. Adopting an epistemological stance is, as suggested earlier, an important decision to consider when shaping and developing the methodology.

This research study pulls pedagogical methodologies from Constructivism to align with the ‘experiential’, ‘quantitative’ and ‘qualitative’ knowledge domains of daylighting, seeking to provide epistemic experiences. Epistemic experiences equip designers with new translations (or a fresh view of) of scenarios/architectural space. I have defined an epistemic experience as occurring when a designer creates a new immersive and integrated relationship between previously unconnected concepts. For example, this may be a designer’s actions towards a space defining a new value for it, through haptic, visual or verbal engagement. Additionally, where new connections can be seen to be explored by a designer, between an architectural space and an abstract design concept, this too can be called ‘epistemic,’ attributable to the new understanding of the scenario in both an abstract and contextual way. Therefore, it was hoped that the following scenarios could be analysed:

- changes in epistemic understanding and approach dependent upon specific design project generators such as design experiences or new connections created through workshop interactions
- changes in ontological understanding of the characteristics of light and its complex relationships with built space through exploring relational values.

Each workshop set-up for this research study was informed by these observations and expectations.

In summary, this definition is particularly important when we consider daylighting within spatial design contexts. When working with light, designers seek to use abstract principles in, most often, contextual settings requiring specific applications. The designer pursues translations and conversions (application) between these modes of thinking through, amongst other things, application of abstract principles. Experiences can be built upon to strengthen design knowledge and connections made attach associations to these epistemic insights giving “value” to previously unrealised concepts.

4.7 The rationale for a workshop format?

A design studio workshop format was proposed to provide an appropriate scenario to explore the chosen themes, record and observe the selected groups of “community of practice”. (Cross, 2011) and (Lawson, 2006) identify common processes within design that provide direct relevance for the ethnographic methodologies of this research study. Their case studies demonstrate the application and discussion of protocol analysis of designers within designed, recorded scenarios with verbal, post-rationalised discussions. In (Schön, 1984) and (Schon & Desanctis, 1986) the analysis carried out with design students in educational contexts and the subsequent critiques of this (Mewburn, 2012), demonstrate the value of conversational analysis in design studios and the dangers of bias in coding and understanding design protocol data.

Unlike the artificial environments of Lawson’s (2006) or Cross’ participants for this study, familiar settings would provide some security for the participants through the authentic situation of design studio. It was hoped that this context would encourage the practice of “habitus” (Bourdieu, 1977), yet still provide opportunity for acceptable minor “disruption” (Garfinkle in (Turner, 1974)) of normal “community of practice” through interventions of some familiar and unfamiliar prescribed workshop tasks.

This research study aimed, through observation techniques, to achieve insights into how participants from the architectural “community of practice” engaged in design practices in relation to daylighting. Workshop explorations were set up to identify and test this process. These scenarios tested where and when practical *and* theoretical connections were made between daylighting schema, the external environment and the interior spatial conditions and how this impacted on proposals. This highlighted successful, or otherwise, methods of translation suiting the “designerly ways of knowing” of the spatial design process. The Workshops began to question how it could be found when these moments occurred in order to channel them or increase the frequency of occurrence?

By observing design moves (Goldschmidt, 2014), within “indigenous” architectural design scenarios, through description or other means it was hoped that it would be possible to “evidence the deliberative outcomes they produced” as they considered daylight within architectural contexts.

To ensure the cyclic and reflexive nature of the research study, focus groups were held. These were held at the end of each set of workshops: i) the Pilot Study Workshops, ii) the main Research Study Workshops. Further, discussions at the end of each Workshop were in some instances expected to work as focus groups as they provided an opportunity for the Workshop facilitator and participants to discuss findings. Reflections from these meetings were then shared with the participants and evaluated for shared understanding of the workshop events. These were carried out to allow theorising of this practice and reflections of the workshop and proposals for further study and evaluation.

4.8 Pedagogical Methodologies Within Workshop Scenarios

An ethnomethodological approach was chosen to allow daylighting design pedagogy to be explored with novice spatial design students in an educational studio context. This framework was considered appropriate for this study as ethnomethodology is a study of ethnomethods or “people's methods” (Garfinkel, 1984) and is interested in the meaning-making processes of interpretation that can be identified in “interaction” (Celine-Marie, 2011). Further,

> *[E]thnomethodology provides tools for apprehending and analy[s]ing the interpretive practices through which people assemble what then comes to be seen as objective features of social life… it provides tools for examining how people's daily actions and practical reasoning produce the appearance of a stable, objective social reality.*
>
> *(Celine-Marie, 2011), p. 2.*

Using this methodological approach allowed daylighting tools to be investigated through participants interactions with them and each other in this process, in a familiar (everyday) studio setting. It was expected that exploring daylighting design methods in this way would allow investigations into their potential within this selected research study environment. Additionally, it was anticipated that the behaviour of participants (their reasoning through actions and language) would begin to reveal participants’ current understanding of daylight and their motivations and priorities when engaging with it.

Chapters 2A and 2B defined a gap in existing pedagogical knowledge and design approach to daylighting within spatial design, clearly divided two overarching ontologies for daylight (qualitative and quantitative), distancing them from valuable integrated approaches within design practice and pedagogy. The objective of the research study was therefore to find methods to explore the possible "translations" (Evans, 1986) between daylight's 'numbers' and the resulting "aesthetics" of the spatial design, encouraging the integration of these approaches. Findings from the questionnaires in Chapter 3 are presented to support the case for new pedagogical approaches to encourage interpretation and translation of quantifiable measures of daylighting in architectural communities.

The chosen pedagogical methodology within this research therefore necessitated a good fit with the evolving nature of the research questions, to allow sequential unfolding and investigation of themes and to ensure application of the appropriate methods for the participant groups and research setting. Further, the pedagogies explored in this research study seek to align with a constructivist methodological approach (refer to section 4.6), inviting physical, experiential learning of daylight's characteristics *in collaboration with* numerical data and digital modes of learning to provide connections and "translations" (Evans, 1986) to develop relationally.

4.8.1 Physical explorations

> *There is a thingness to light that one cannot form with one's own hands. Light is not verbal; we need images, we need spaces.*
>
> *(Holl, 2000) p139.*

The selected methods for these physical explorations sought to align with Gustina's (2011) and Brandston's (2009) aspiration for designers to "see" light, to "touch" light, through haptic, heuristic learning (Pallasmaa, 2009) and value "perceptive experience" (Farías, 2015), (Pallasmaa, 2009) of real, visual or "narrated" architectural spaces (Brown, 2004) through reflecting and recording. Through exploring these methodologies we expect to discover what allows designers to distinguish these varied, dynamic, characteristics of light and how we might "develop an understanding of their perceptual effects in architecture" (Rockcastle, 2013), p. 2.

This experiential pedagogical approach required the introduction of tools to encourage explorations, aligned with these approaches to ‘experience’ daylight in a variety of ways. Although tools currently exist for the analysis of daylight, my research thus far has demonstrated that what does not exist is an approach (with an aligned toolset) that allows the objective numerical analysis to sit comfortably with the subjective, qualitative aspects of daylight. Therefore, the selected tools also needed to serve as translators between these opposing domains for daylighting to provide a holistic understanding and demonstration of this approach. Physical and virtual ‘methods’ defined as workshop ‘tasks’ were proposed as ‘tools’ in the Pilot Study Workshop and, with some further amendments, developed and re-introduced in the main research study workshops.

4.8.2 Virtual explorations

Hanna (1996) identifies the need for tools for architectural designers to “enable the prediction of daylight levels quickly and frequently”. However, he also proposes the need for tools to allow a “subjective appraisal of the character of daylight” by suggesting that tools using metrics alone do not give any indication of this. “Useful information in the form of an illuminance from daylight and artificial light or daylight factor map at the working plane height can be generated quickly” (Hanna, 1996). This may indeed prove useful for a lighting designer needing to check lighting levels for compliance with regulations or recommendations but it is questionable how “useful” this information is to architectural designers and designers in educational settings? Will the information produced by this analysis be clearly understood and is the information created actually displaying information that is relevant or helpful for the spatial designer?

Further, Hanna (1996) suggests that using computers allows for an iterative design process that is not possible using metrics of physical scale models. Hanna considers it necessary for designers to “know how to relate light units of illuminance and luminance…to a perceptual schemata into spaces and buildings”. However, if we examine any of the current lighting software packages available it soon becomes very clear that many of the processes for the resulting output values displayed are hidden processes thereby hiding the relational values from the designer using the software. It has been chosen to employ computer simulation tools within this research study however to challenge the required input and output values for their accessibility in participants' understanding. The language of these elemental quantitative values needs to be clear within the lighting design software. The computer simulation tool selected is also reviewed for its alignment with the pedagogical methodology of learning threshold concepts through experiencing qualitative and quantitative values as simultaneous, if not fully balanced ontologies for daylight.

In a physical model it is very easy to change a surface colour (thereby a reflectance value), or in a hand calculation for an applied metric as these values have been considered as compositional elements of the space. Due to the complexity of the architectural model composition or user interface of the software package the concept of each interior element having relational value to each other and the subsequent outcome may not be highlighted, let alone understood by designers. Methods of translation are therefore necessary to aid the designer who may be engaging with a new CoP or threshold concept that does not align with their current ontology.

4.8.3 An approach to translational activities in design

The word 'translation', often implies that connections can be made between one context and the other with little loss of meaning such as, "to move something without altering it" (Evans, 1986). This is therefore a challenging phenomenon to address within design pedagogy as much of design relates to design meaning and tacit translation. Ethnographic linguistic studies have shown that between communities translations may lose some of the initial value. Translation tools in this research study are therefore not seeking to find an exacting definition in an alternative language but instead, through the "contextual relations" (Catford, 1965), between forms and aspects of the context in which the forms are used we make sense of the meaning of the concept in translation. "That concept must in turn be connected to the translation phenomenon"[Malmkjær, 2011, Meaning and Translation].

However, whilst working with epistemic objects to evolve ontological understanding, (Land & Meyer, 2006) (p.22) suggest that learning also involves the occupation of a liminal space during the process of mastery of a threshold concept. The idea of liminal states describes the conceptual transformations students undergo in design education and highlights that learning is both affective and cognitive and that it involves identity shifts which can entail troublesome, unsafe journeys (Cousin, 2006), pp. 4-5. Liminality is the quality of ambiguity or disorientation that occurs as a designer is in the process of creating and working with the design idea. At this point in the process the designer no longer holds their previous values but is also not yet fully transitioned to new values. This is a challenging for many educators to grasp as leaving a student in a liminal situation can be “worrying and much less gratifying than perfect mimicry possible through straightforward apprenticeship models” (Land & Meyer, 2006). However, liminality is fundamentally necessary to allow for epistemological re-positioning. New ontological understandings form and take hold, often when the participant has “realised their previous thinking is questionable but the new idea has not yet been resolved” (Cousin, 2006).

It was therefore decided to explore with student participants what would appear to be the threshold concepts for daylighting design “in need of mastery” (Cousin, 2006), p. 5. However, with this consideration of the liminal states of novice designer particpants, it was important to ensure that the workshop tasks and settings allowed for participants to make design decisions and create design actions without any reprove as they explored the new, unfamiliar daylighting concepts. Although the research study was set in an educational design studio context, the tasks were therefore not assessed.

Additionally, the time required to complete each task was considered to allow for multiple options to be tested and the variations in answers discussed at the end of each session. With these measures in place, design scenarios could be created, analysed and understood for their value in shifting understanding of the “threshold concept” (Cousin, 2006) ensuring the processes ‘in-between’, where liminal states often occur, would be given space and consideration.

In this research study translation is assumed to provide connections of meaning between misaligned design agendas or differing design ontologies. Translation in this context seeks to provide a bridging of shared values between communities. Additionally, this definition of translation also implies that it is possible, even if meaning is lost through shared values, to find ways to understand the threshold concept sufficiently. It can also provide associations and relevance to the architectural design community which, in turn, may apportion new, previously unknown “value” to daylighting concepts. With this understanding of translation in mind, the workshops were designed to advance these connections through pedagogical approaches to encourage haptic, visual, numerical and verbal translations to occur.

4.9 How can a methodology using “Threshold Concepts” inform daylighting pedagogy?

The idea of threshold concepts emerged from a UK national research project into the possible characteristics of strong teaching and learning environments in undergraduate education[1]. In pursuing this research in the field of economics, it became clear to Erik Meyer and Ray Land (2003, 2005, 2006), that certain concepts were held by economists to be central to the mastery of their subject. These concepts, Meyer and Land argued, could be described as ‘threshold’ ones because they had certain features in common. In a similar way design knowledge is decribed by Cross (2011) as having “first principles” or “guiding principles”. It is only when these principles are available to the designer that any design conflict of the “ill-structured domain”, can be resolved. “Guiding principles…can be seen as a design philosophy or a set of values about what designers hold as important in their own domain”. It is clear that guiding principles can have value, particularly when distinctive to the field. For this study, it was therefore proposed to develop guiding principles appropriate for use within daylighting curriculum specifically as these are not documented clearly in any publications.

> *If we want to develop an understanding of the pedagogy of the subject we teach, we have to start somewhere and making sense of what seems central and often difficult to grasp by most learners, is a good place to begin our inquiry. A tendency among academic teachers is to stuff their curriculum with content, burdening themselves with the task of transmitting vast amounts of knowledge bulk and their students of absorbing and reproducing this bulk.*
>
> *(Cousin, 2006), p. 4.*

In contrast to the pedagogical approach above, a focus on threshold concepts (guiding principles), enables teachers to make refined decisions about what is

[1] Enhancing Teaching-Learning Environments in Undergraduate Courses - http://www.tlrp.org.

fundamental to a grasp of the subject they are teaching. It is a “less is more approach to curriculum design” (Cousin, 2006), p. 4. This pedagogical epistemology aligns with Parker Palmer’s discussion in which he suggests that teachers will do well by demonstrating through one small aspect, the depth of knowledge and possibilities within a field (Palmer, 1998). His approach introduces one threshold concept at a time and the potential it has to define many other aspects within the breadth of the field, rather than volumes of unconnected facts that are not only difficult to remember but also difficult to apply in any real context.

For example, Meyer and Land (2006) identify characteristics of a threshold concept:

- It is transformative because it involves an ontological as well as a conceptual shift.
- A threshold concept is often irreversible; once understood the learner is unlikely to forget it
- It is integrative in that it exposes the hidden interrelatedness of the phenomenon.
- A threshold concept is likely to be bounded in that “any conceptual space will have terminal frontiers, bordering with thresholds into new conceptual areas” (Land & Meyer, 2006), p. 6. This implies a curriculum design perspective that aims for a research-minded approach to mastery in which there is always space for questioning the concept itself.

A threshold concept is likely to involve forms of “troublesome knowledge”; David Perkins defines this as “that which appears counter-intuitive, alien (emanating from another culture or discourse), or seemingly incoherent” (Land & Meyer, 2006). From this view, mastery of a threshold concept can be inhibited by the prevalence of a ‘common sense’ or intuitive understanding of it. Getting students to reverse their intuitive understandings is also troublesome because the reversal can involve an uncomfortable, emotional repositioning and ‘liminal’ state of thinking.

It is therefore proposed for this study that threshold concepts are formed, considering the pedagogical goals of those included within the literature review, identified as the key educators and researchers and texts in the domain of daylighting design. However, in addition, these threshold concepts will be both flexible in their breadth of knowledge necessary to understand them, yet specific and clear as to the specific knowledge or skill intended to be learned and its intended use.

If threshold concepts are to be established rationally the ontological perspectives of the researcher selecting and defining them cannot be ignored. It was therefore proposed that the selection of concepts would be developed as a combination of concepts included within the pedagogical case studies (see Chapter 2B) but would also need to align with the emphasis in this study of “relational” understanding of daylight to architectural space.

4.10 How can threshold concepts for daylighting be defined?

> *Light acquires meaning in architecture relationally, that is, as part of a sequence of luminous relationships.*
>
> *(Millet, 1996), p. 3.*

It was therefore significant to select lighting concepts that demonstrate relational associations. It is in the understanding of the behaviour of light that a designer can therefore gain an understanding of light and the characteristics of interactions; physically seen and then possibly predicted in alternative contexts. “By observing how light behaves, we can work with it to reveal architecture” (Millet, 1996), p. 2. Millet highlights the following rules as key principles of lighting and those that invited ‘relational’ notions are listed below:

- *Reflection is reciprocal: the angle of reflection equals the angle of incidence for specular surfaces.*
- *Surfaces with a matt finish spread reflected light diffusely and evenly in all directions.*
- *As a surface is turned away from a light source, it receives light at an angle, and the illumination on the surface is reduced by the cosine of the angle of incidence – it drops off.*

> *(Millet, 1996), p. 2.*

To consider these ideas in the focussed context of daylighting, rather than that of the wider domain of lighting design, it was also necessary to include also include the sky and sun as the distinctive light sources.

Therefore, a set of relationships were derived from Tregenza and Wilson's (2011), *Daylighting: Architecture and lighting design*, Reinhart's (2014), *Daylighting Handbook I - Fundamentals, Designing with the Sun,* Traverso's (2015) *Modelling Daylight*, with each definition of daylighting design suiting either 'physical' or 'numerical' relationships.

- Physical - solar trajectory, time, materiality, form related compositionally (also see Millet's descriptors above)

- Numerical – DF, luminance contrast (ontological *what* and epistemic *when* relational daylighting metrics are useful)

It was therefore proposed that the selection of concepts would be developed as a combination of concepts included within the pedagogical case studies (Chapter 2), as standard practice, but would also challenge these "relational" connections, valuing each through their contribution to architectural space.

With these notions considered, a list of threshold concepts was generated, identifying three key relationships within daylighting that required engagement:

1. **What are the dynamic characteristics of daylight (physically and numerically)?**

2. **How can the relationships between direct sunlight, diffuse daylight and shadow be defined?**

3. **How can we propose an internal daylighting condition for a space through knowing the sky conditions filtered by the formal architectural envelope (physically and numerically)?**

These concepts therefore invited engagement with 'relational' daylighting metrics. From Chapter 2A some metrics discussed have a clear physical relationship to the variables, perhaps improving opportunities for understanding concepts that are also strongly theoretical:

- DF (Average and Median) – Relationships to glazed area, areas of material surface reflectances, size of room, angle of unobstructed sky.

- No Sky-line – Relationship of building user to view of the sky.

Those metrics, where the relationships were less clear, were those that required CBDM to carry out the calculations. Metrics such as Daylight Autonomy (DA) and Useful Daylight Illuminance (UDI) both use dynamic principles, are illuminance based, and incorporate climatic data over the whole year, producing spatial maps that seeks to clarify the hours when a space will have sufficient daylight to carry out the tasks without additional artificial lighting. Results are however generally displayed as an average (or median to conform with new BS EN 17037:2019 Daylight in buildings) and consequently do not display a relationship of the results to the process carried out. However, as these metrics are becoming increasingly important it was decided to explore these metrics also as part of the research study to assess their possible contribution to daylighting pedagogy.

In summary, the insights revealed in Chapters 2 and 3 allowed for the proposition of threshold concepts to challenge and debate within the pedagogical setting of this research study. The subsequent workshop designs sought to follow these broad principles and encourage participants to interact, both physically and numerically with ’relational’ daylighting concepts and values.

Chapter 5 Pilot Study Workshops

5.1 Introduction to workshop methods for pilot studies

Motivated by the need to explore the uniqueness or distinctiveness of daylighting design methods, techniques, media and tools within the field of spatial design, I developed workshops to provide an opportunity for task-based data collection and analysis. A series of pilot study workshops were created to explore how new pedagogic approaches for daylighting could enhance opportunities for engaging with daylight within design studio and lab-based workshops.

These workshops were created to find insights into the use of exploratory ethnographic methodologies to discover pedagogical tools to promote the understanding of the "thingness" (Holl, 2000) of daylight within the spatial design process. The workshops were developed to challenge the ontological perspectives identified within the pedagogical review (in Chapter 2B) and provide data to assist discovery of tools for daylight through exploratory processes. It was considered critical to find tools to increase understanding of the behaviour of daylight in architectural space as the pilot study questionnaires and literature review had demonstrated existing tools were underutilised.

The data collected from designers taking part in the workshops was used to develop insights into the processes of learning about daylight as a "novice" (Lawson, 2004) spatial designer, using proposed daylighting threshold concepts (as described and outlined in Chapter 4). It was expected that novice designers would create an appropriate group for study as their design methodologies (Cross, 2004) and ontologies would be less established. Tasks were created to allow both an evaluation of the suitability of the proposed selected daylighting threshold concepts and the learning methods used in each case for the selected study group.

It was hoped that implicit understandings of daylighting design concepts would be made explicit through the methods used, such as group working and focus group discussions. Verbal protocol analysis is known to provide evidence of "externalisation of thought processes" (Cross 2011) through sketches etc. which are fundamental to the design process. Therefore, research was carried out by recording, observing and subsequently evaluating learners' engagement with the workshop tasks whilst examining the discussions and actions taking place. The pilot study workshops were used to explore current didactic methods (as discussed in Chapter 4), to support existing methodologies.

These workshops were also intended to test the significance and relevance of my research questions and support a refined set of research questions informing and supporting a focussed framework for a subsequent study.

5.1.1 Pilot Study Workshop – Method objectives

The research methods used aligned with an ethnomethodological approach (as defined by Celine-Marie (2011)] described in Chapter 4, using a combination of protocol and conversation analysis of practical lighting workshops. The initial set of workshops, forming the pilot study were informed by the pedagogical approaches discussed in Chapter 2B, building on findings from Chapter 3 (design student and practitioner questionnaires), and methodologies of learning design process as reviewed in Chapter 4.

To create a basis for the proposal of new, and re-considered pedagogies it was understood to be valuable to first evaluate existing pedagogies and approaches against the criteria noted above. Using this approach, the selected practical set-up of each workshop and participant tasks were initially informed by known, standard approaches and methods (as discussed in Chapters 2 and 4):

- The broader area of **design protocol explorations**; Cross (2006), Lawson (2004, 2006) and Garfinkle (1967) used for design protocol workshop design, methods for data collection employed and analysis methods for the data collected (Chapter 4.4).
- The focussed, existing approaches to **daylighting pedagogy** of Traverso (2015) physical models with solar trajectory studies, Theodorson (2012), Gustina (2011) case studies to "see" light and Stannard (1998) experiential field trips to case study buildings, all highlighted as valuable pedagogical sources within the literature review (Chapter 2.4.1,4,5 and 8.) with which to base the workshop tasks.
- The workshop tasks as **architectural daylighting case studies** identified through review of Gustina's (2011) building case studies selected for his lighting workshop, Plummer's (2009), *The architecture of natural light* and

(1987) case study discussions, Fontoynont's (1999) *Daylight performance of buildings,* case study buildings from showing graphical daylight analysis and current building case studies included within Rockcastle, (2017), *Contrast measures for predicting perceptual effects of daylight in architectural renderings* to ensure contemporary examples were reviewed and included.

The pilot studies within this chapter were therefore prepared to allow appraisal of existing pedagogical approaches as reviewed in Chapter 2B and teaching practices I had used with design students previously including; solar trajectory teaching with stereographic sunpath charts, VE simulation using IES software and Edenapp* for mobile phones.

The research study aimed to identify knowledge domains (both distinct to daylighting and any shared with other fields) by querying what knowledge is necessary for daylighting whilst hoping to challenge the selected daylighting threshold concepts outlined in Chapter 4. This was made possible through the questioning and analysis of the use of the following experiential qualitative and quantitative learning methodologies:

- **Learning methods about daylight as quantitative** – The location of the sun using solar path charts, climatic daylight conditions data, measurement of daylighting metrics. In particular, this also included an introduction to the use of *Edenapp, a unique Daylight Factor measurement app created and developed by the researcher as part of a previous team pilot study for architectural environmental design teaching but not yet appraised for its use within interior design teaching contexts specifically. (Refer to Appendix V for published paper highlighting previous results with architectural environmental design students).

- **Learning methods about daylight as qualitative –** Participant observations informed by experiencing real and virtual lit environments through field visits, visual and written sources, drawing and physical modelling of spatial/material/atmospheric conditions.

- **Selected daylighting threshold concepts** - Small group learning activities to introduce specific daylighting threshold concepts through the broader scope of spatial analysis and design using the quantitative or qualitative methods noted above.

The data collected from the workshops sought to question these methods and challenge the selected daylighting threshold concepts, mapped on to the following measurable criteria:

- **The clarity in the participants' definition of the selected daylighting threshold concept? -** analysed through examining protocol and conversational analysis data in the carrying out of the designed quantitative or qualitative tasks and learning methods, participants' sketchbook outputs, analysis of focus group discussions and researcher's observations.

- **The learner's perception of the usefulness and success in use of the daylighting threshold concept and/or method?** (indicating opportunities and scope for participant to use this method again to progress a design or for inclusion in another context) - through focus group conversation analysis and questionnaire feedback.

5.1.2 Pilot Study Workshop – Learning Objectives

To ensure that participants' behaviour was as authentic as possible, familiar "Constructivist" teaching techniques currently used. In particular design teaching studio contexts and familiar studio workshop methods were chosen. This included model making, hand drawing investigations and small group discussions. Additionally, to improve the authenticity of results, it was also considered important that participants would be familiar with the learning in environments where the research workshops were taking place, such as their design studio or lab. The Pilot Study Studio workshops were designed to fit within the current architectural educational setting. This was to ensure continuity of results through weekly analysis within the same environmental setting and participant group, with the aim of producing results from real studio contexts without the added complexity of unfamiliar, simulated situations.

It was decided to make the tasks focus less obviously on daylighting threshold concepts to encourage a holistic design approach. The tasks given sought to develop the creation of the spatial ambience through given case study site contexts, spatial volumes and explorations of materiality with light. It was anticipated that the most suitable methods to reveal the underlying connections, and significant relationships between light and these other "elements" (Brooker, 2008) of spatial design might become more apparent within the results if the holistic nature of daylight within architectural space was demonstrated. Rather than daylighting being consistently presented as a singular elemental design device, daylighting would be included within the full spatial design explorations of the workshops.

A set of learning objectives linked to the tasks and threshold concepts was created to clarify and define my own expectations of the tasks and their resultant expected output. It was assumed that these objectives would also form the basis of discussions with participants in the focus groups subsequent to the workshops. They sought to investigate and identify if, what and when learning had taking place. However, although the workshop tasks were discussed with participants, these learning objectives were not discussed with the participants prior to taking part in the workshop to ensure the data collected was as representational as possible.

The learning objectives and tasks for analysis were set against the threshold concepts (as outlined in Chapter 4, numbered below):

1. **What are the dynamic characteristics of daylight (physically and numerically)?**

Tasks to - describe daylighting concepts using terminology, numeric measures and graphic representation, appropriate to the audience to convey the lit ambience eg. Using technical terminology when required to convey visual ambience and vice versa.

2. **How can the relationships between sunlight, diffuse daylight and shadow be defined?**

Tasks to - represent the ambience of a lit architectural space (through existing and innovative methods of making and drawing) with an informed understanding of the behaviour of daylight (for example not showing sunlight coming from two directions at once as had been previously observed).

3. **How can we propose an internal daylighting condition for a space through knowing the sky conditions filtered by the formal architectural envelope (physically and numerically)?**

Tasks to - predict the effect that daylight will have on an architectural space that has not yet been physically realised (and therefore allow for informed manipulation of new and existing spaces), again, through an informed understanding of the behaviour of daylight in different spatial volumes and with different material finishes.

5.1.3 Pilot study workshop type experimental set-up ethical considerations

This section includes the creation, application and issue of consent forms. It also defines any academic interest/relationship issues in this particular study related to student and tutor expectations.

This study aimed, through observation techniques, to achieve insights into how groups of student participants from spatial design engaged, and could better engage in design practices in relation to daylighting. By observing design "moves" (Goldschmidt, 2014), within familiar spatial design scenarios, through description or other means it was hoped that it would be possible to "evidence the deliberative outcomes they produced" as they considered daylight within architectural contexts.

To ensure participants had the motivation to take part it was considered important to select participant groups that would benefit from the research study. It was therefore imperative to design in tasks that would provide participants with outputs that would be useful to them, as a reminder of the study and learning situations they had taken part in, or outputs that could form part of their on-going design portfolio.

Participant selection for the research study was challenging as, to avoid conflict of interest and to ensure participants behaved in as an authentic way as possible, the experimental set –up had to be in a non-assessed environment (participants' outputs were not assessed for any credits, points or examination purposes) and therefore was required to be optional attendance. It was therefore proposed that participants would be made aware of the research study and the times when the research was taking place within their timetable and an opt-out option would be provided should they choose not to attend.

The location for the research study was fortuitous as it provided a comfortable, familiar studio environment for all participants (for every session). No experimental set-up was required as such so that results were expected to be as authentic as possible without participants' behaviour adapting to their understanding of the researcher's expectations. Additionally, the proximity of suitable case study buildings in the vicinity allowed for, and encouraged, all participant groups to attend and 'experience' the real daylit space. Continuity of research was also possible as each group of participants attended weekly and findings from the previous research session could allow for modification and preparation for the next.

An application was sent and accepted by the ethics committee in 2015 and again a revised application for 2016 - 2017 to continue with the research study. Every participant was given a form to complete that not only provided information on how their participation and outputs would be used but also a request for a contact email should any of their outputs be published in future projects or publications (refer to Appendix V 5 for the sample form). It was made clear that all recordings, transcripts from the recordings and outputs would be anonymised. Further information on the data recorded and full method of analysis is included in Chapter 5 Methods.

In summary, the perspective chosen for the research; explorations of a design tutor within a spatial design education setting, with design student participants, was understood to limit the scope of the direct application of the findings to similar contexts but, the advantages of this particular setting were seen to be two-fold.

- The pedagogical explorations provided a rich source of experimental settings; varied participant groups, time to collect data and develop reflective discussions and focus groups and the opportunity of repetition of pedagogic scenarios for investigation. Critically to this study, and the authenticity of the data collected, it was possible to provide opportunities to work with participants in workshops that were not assessed as part of an examination, thereby demanding less pressure on the participants to perform or conform to a particular assumed or imagined expectation other than those arising within the workshop itself.

- The application of the methods trialled in the workshops provided real data and outlined practical applications and pedagogical approaches for similar contexts; design educators who wish to engage more with future daylighting design demands through pedagogical approach, workshop methods and learning scenarios in architectural education whilst meeting growing sustainability agendas and student expectations.

5.1.4 Pilot Study Workshop Experimental Set-up

The research explorations aimed to identify insights into design processes and knowledge acquisition through the application of varying tools in daylighting design scenarios and the subsequent participants' responses. Design studio, case study building field trips and computer labs were chosen to test these methods through controlled scenarios and observational techniques.

Each studio session was set up using the same experimental set-up for each scenario type:

Set 1 - Studio Workshop (approx. 30-40 participants)

Participants arrived and sat in their own studio desk space. This was followed by an introduction to the workshop and the tasks involved. No other participants other than those taking part in the workshop were working in the space. Each workshop was two hours long. Participants worked either individually or in pairs (refer to task outlines following).

Set 2 - Field Trip Workshop (approx. 20-30 participants per group)

Participants arrived at the venue at allocated time. This was followed by a group introduction to the architectural space, the workshop and the tasks involved. Each workshop was one hour long. Participants worked either individually, in pairs or as small groups of three (refer to task outlines following).

Set 3 - Computing Lab Workshop (approx. 20 participants per group)

Participants arrived and selected a fixed computer space in a computing lab. Participants shared computers, 1 no. computer per group of 3 participants. No other participants other than those taking part in the workshop were working in the space. This was followed by my introduction to the workshop and the tasks involved using a large demonstration screen. Each workshop was one hour long. Participants worked to complete the tasks as small groups of three (refer to task outlines following).

Focus Group Discussion (approx. 8-10 participants per group)

Participants were asked to attend the focus group session after the workshop events. The discussions were facilitated and led by 2 of my colleagues (1 hour each, sequentially). The discussion facilitators worked with a set of guided questions I created to guide conversations. It was agreed that the discussion could progress from the exact questions given but the facilitators were asked to bring the focus back when appropriate to ensure all questions were covered. An outline of the pilot study workshops can be seen in the table on the next page.

		Pilot Group A (Interiors)	**Pilot Group B** (Architecture)
Pilot Workshop Set 1	'Experiencing Interiors Sketchbook Project'	- Intro presentation - Case study based - Drawings (+ pantone) - Presentation on modelling solar path - Model: intro presentation to lighting measurements and terminology - Focus group for participant feedback	
Pilot Workshop Set 2	'Sustainable Daylight Field Study'		- Presentation on DF, no sky line, measuring illuminance - Nomen workshop tasks - Talk from Client - Tasks in-situ: > Drawing > Physcially define 'no-sky line' > Average DF using hand calc > Measure point DF using EdenApp
Pilot Workshop Set 3	'Sustainable Daylight VE Study'		- Short intro to software in lecture theatre - In lab imported 3D model - Tested sunpath > DF% and absolute illuminance values - Change the model to see the changed results and 'post-it'

Figure 15 Pilot Study Workshops with participant groups and tasks.

5.1.5 Workshop conversations – The role of conversation in group design explorations

Qualitative data collection was deemed most relevant to provide information on participants' actions, expressions and language for the pilot study workshops and ensure conversations in the process of design making could be recorded and analysed. Visuals were also used within the workshops, not only as source material but also as outputs through photographs or drawings.

Conversational accounts of the workshop experiences were understood to be important data, "not only for the particulars of what was said", but also as pointing toward, "a mass of unstated assumptions" (Heritage, 1984), p.181", (Celine-Marie, 2011). Sound recordings were considered necessary to allow analysis techniques that could later examine the learners' responses to the workshop tasks and provide insights through the conversational data collected from the participants. Analysis of parsed conversations were used to find implied tacit knowledge through words and visible actions. This analytical focus (documentary method) treated data as pointing to, or standing on behalf of, a presupposed underlying pattern (Turner, 1974), p. 78. "The appearances and the underlying patterns are reflexively related. The point of documentary analysis is to examine the tacit knowledge underlying what is said that enables 'what is said' to make sense" (Pascale, 2007, p. 11).

5.1.6 The Pilot Study Participant Groups

To investigate pedagogical methods for learning about daylighting design it was necessary and appropriate for the participants to be novice designers (architecture and interior designer students in this context), or so-called "learners" of design. (Peterson & Merunka, 2014) comment positively that college students may be appropriate research subjects in certain situations, especially if they represent a population of interest. For example, architecture students are future architects, which may make them appropriate for studies in this domain. Successful examples of using domain specific participants is evidenced by (Ahmed et al., 2003) and (Peterson & Merunka, 2014).

Further reasons for selecting these participant groups was two-fold. Firstly, example pedagogical approaches and design exercises used by other lighting educators, as discussed in Chapter 2, have been conducted with student participant groups. This research set-up can thereby provide a similar situation for some comparative analysis. Secondly, these groups of participants allowed for a research context with uninterrupted, direct engagement in workshop sessions within timetable and curriculum. Participants took part in design studio and/or computer lab or field trip workshops and these sessions were observed and recorded as participants worked on set tasks within familiar studio or lab contexts, exploring learning methodologies through case studies with the time to do so on a voluntary basis.

Two participant groups were studied in the pilot study:

- **Pilot Group A** – A mixed group of design novices ranging from 1st year Interior design students with less experience up to Masters level Interior design students, some with design work experience, with different nationalities and design educational backgrounds.

- **Pilot Group B** - created from a larger architecture year 2 student cohort. This larger group was split into smaller sub-groups for digital lab work and field trips. These participants only took part in Pilot Workshops Sets 2 and 3 due to time constraints and curriculum demands.

From the larger cohort (participant group A or B), participants were placed into sub-groups of three to encourage discussion and provoke realisation of others' values and experiences of the lit environment.

Workshop attendance was optional but encouraged. To ensure the involvement of the researcher as design tutor had as little detrimental effect as possible, it was important that the workshops were not an assessed component of any participant's curriculum. This sought to avoid participants feeling additional pressure to perform in unauthentic ways during workshop tasks and focus groups (see Chapter 4 for further information on this approach). Therefore, the work created, although not assessed, was simply assumed to be a beneficial addition to each student's portfolio.

5.1.7 Pilot Study Workshop Analysis Methods

Analysis methods were chosen to trial different types of analysis of workshop findings but also to suit participant groups, and their time and the effort involved for participants in the feedback. Focus groups were used for Group A as it was possible and practical to schedule in discussion sessions towards the end of the workshop set. Group B provided feedback through a questionnaire (Refer to IES VE Workshop notes in Appendix V) which was straightforward to implement with the large participant group and was included without intrusion into the existing timetable.

Additionally, observations and feedback were received from colleagues who either facilitated the workshops or focus groups. Further, as the role of researcher, my own observations during workshops were recorded.

Conversational analysis of the focus group data was carried out in NVivo to primarily explore language use. NVivo is a qualitative data analysis (QDA) computer software package known to be appropriate for qualitative researchers working with very rich text-based information (such as focus group interviews). I took part in training on the use of the software and found that the analysis of transcripts was possible. NVivo was therefore considered a useful tool to use for analysis of the pilot study focus group transcripts.

5.2 Pilot Study Workshop - Introduction Experiencing Interiors Sketchbook Project Pilot Group A

The first set of workshops (Pilot workshop Set 1) commenced each week with a Powerpoint slide show. This presentation covered the workshop tasks, any extra resources or materials to be used (such as drawing equipment) and images/movie clips covering a case study each week as a ten minute introductory session in the studio space. This included a short introduction to each of the selected case study buildings through the approach of the designer of the building with photographic images and hand drawings by the designer (see Appendix V for examples of these slides). Strategically, little emphasis was placed on the daylit qualities of the space so that the participants were encouraged to think of the daylighting as part of the holistic design of the space. The workshops were entitled “Experiencing Interiors – Sketchbook Project” to emphasise the phenomenological approach to the workshops. Additionally, the introductory slides served to provide objective information to inform participants about the building type, materials and location.

Case studies were selected from my own architectural experiences in visiting them and/or through investigations into case studies used by other educators (see Chapter 5.1.1), finding them to be strong examples of daylighting design. In particular, Ando’s Church of The Light, was included as this is cited by many as a seminal architectural space that uses light in an extraordinary way (Steane, 2011), and (Plummer, 2009) and as a ‘generator’ of the formal arrangement of the space.

> *The Church of the Light embraces Ando’s philosophical framework between nature and architecture through the way in which light can define and create new spatial perceptions equally, if not more so, as that of his concrete structures.*
>
> *https://www.archdaily.com/101260/ad-classics-church-of-the-light-tadao-ando*

An additional two case studies were chosen to allow more than 1 group to have the same case study. Crucially, this method allowed for some comparison of different interpretations of the same space by different sub-groups of participants:

Figure 16

A - Tadao Ando - Church of the Light, Osaka, Japan (1989), Interior view

B - Zaha Hadid – Maggie's Centre Fife, Kirkcauldy, Scotland (2006), Interior view

C - Peter Zumthor - Serpentine Temporary Pavilion, London, England (2011), Courtyard view

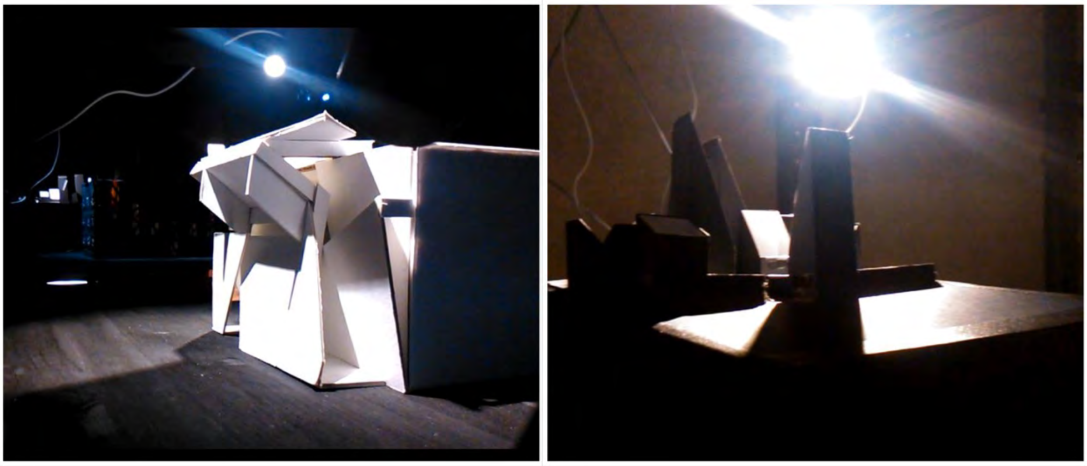
5.2.1 Pilot Study Workshop Set 1 - Tasks
Experiencing Interiors Sketchbook Project
Pilot Group A

Week 1 – Case study 1: Church of the Light presentation and hand drawings
Week 2 – Case study 1: Maggie's Centre presentation and hand drawings
Week 3 – Case study 1: Serpentine Pavilion presentation and hand drawings
Week 4 – Introduction to Solar Trajectories
Week 5 – Physical model making and sunpath evaluations
Week 6 – Physical model making and sunpath evaluations cont.
Week 7 - Introduction to daylight metrics and lighting measurements. Model lighting measurements.
Week 8 – Focus Groups

The tasks listed above aligned with the 3 threshold concepts (outlined in Chapter 4 and in Chapter 5.1), to allow exploration of the behaviour of daylight, to represent it, to model it and to measure it. Weeks 1,2 and 3, participants all worked in sketchbooks to create drawings each week of the case study building presented in the studio. Some participants however chose to create the same case study drawing in multiple ways. Workshop participants were encouraged to use both the drawing techniques that the designers had used for visualising their own space (if they felt this was successful) but also explore and develop their own techniques or media for expression of the lit space. Examples of these can be seen in the Presentations within the Appendix.

Group work started in week 4 when participants were asked to help set up a temporary artificial sun within the studio space. Participants were shown a solar path stereographic sunpath chart for Edinburgh and this was explained, discussed and repeated 3 times, once to each group of approximately 10 participants at a time. Participants were given time to work out azimuth angles and altitude angles for different times of day/year. Each participant was asked to physically mark on the diagram to show their thinking and working out for at least one time/day to demonstrate their understanding and make explicit any misunderstandings. Previous teaching experience had shown that not all students grasped the concept of the use of a stereographic sunpath in a group and often needed one-to-one help using a repeated step-by-step approach. Tasks were initially individual then became group based to allow for conversation analysis during week 4 and 5 during model making workshops.

Traverso's student workshop project in 2012 "Daylight Thinking" via the University of Florida (Traverso, 2015), exhibited at PLDC 2015[1] influenced the experimental set-up for the artificial sun (refer to Chapter 2B 4.7 for further discussion of this approach). Traverso's students had set up models within metal exhibition stands with individual adjustable angle LED luminaire heads secured to the stand, programmed to flash on and off sequentially from three alternative positions indicating the changing position of the sun in the sky and the resultant sunlight patterning in the space.



A B

Figure 17, A and B Images of models from PLDC exhibition 2015

Source: PLDC via verlag publishing

A similar technique was used for this workshop. However, for the pilot study workshops, as this artificial sun was a temporary installation for two hours or less each week, the experimental set up used methods that were practically quick to set up with easily accessible tools. Collapsible tripods were used, carefully positioned around a physical model using three mobile phones acting as light sources with the front screen light of each phone representing the sun in one of the selected key positions. Battery torches had been explored in my previous teaching when sunlight was not available but found to be unsuccessful for the accuracy and security in attaching the torch in the correct location and the profoundly inaccurate formation of shadows in and around

[1] Professional Lighting Design Convention 2015 "An Educated Decision". The experience room had a set of student models set up for conference participants to view https://2015.pld-c.com/. https://www.youtube.com/watch?v=F6I_8wSc10I.

scale models. The torch light was not a parallel beam and distorted the shadows significantly confusing learners with the results. Although torches formed of arrays of LEDs are now readily available this luminaire design still creates significant distortions around the periphery of the shadow so it was chosen not to use this equipment for this reason.

Participants began building a physical, card, scale model of one of the chosen case studies, within a self-selected group (approx. 6 in each group) split into different model building and research roles eg. Measuring and cutting card or finding the latitude and orientation of the case study building location on-line. The choice of case study building was relatively evenly spread across the full study group with 5 models created in total; 2 no. Church of the Light, 2 no. Serpentine Pavilion and 1 no. Maggie's Centre.

In parallel, a short presentation was given to demonstrate the use of a stereographic solar path chart. A stereographic sun chart was placed centrally on a table (A0 size to suit the scale of the models being texted) in a darkened area of the studio space and three tripods were set up to show snapshot solar geometries for three times of the day for a specific day using the latitude for Edinburgh. Participants' mobile phones were then attached to each tripod, at the associated angle using the phone's screen light to represent the sunlight. It was hoped that this technique, using basic photographic equipment, would allow participants of these workshops to repeat this set-up simply and easily at any other time. Participants were then encouraged to try solar trajectories for their case study model locations and shadow pattern analysis outdoors if sunlight was available.

Participants were then encouraged to sketch the position of the sun as it moved to form a visual of the solar trajectory for their case study project as "shadow tracing" drawings. However, it is worth noting here that participants were keen to photograph the sun and shadow effect, rather than draw this sequence as they wanted to test many sun positions.

In Weeks 5 and 6 participants continued with the models and set up an artificial sun testing area each week to allow each group to explore their models in rotation. Models required to be fully enclosed to ensure that no light could leak into the interior space. Fish eye viewing lenses were used through small openings to increase the viewing angles possible.

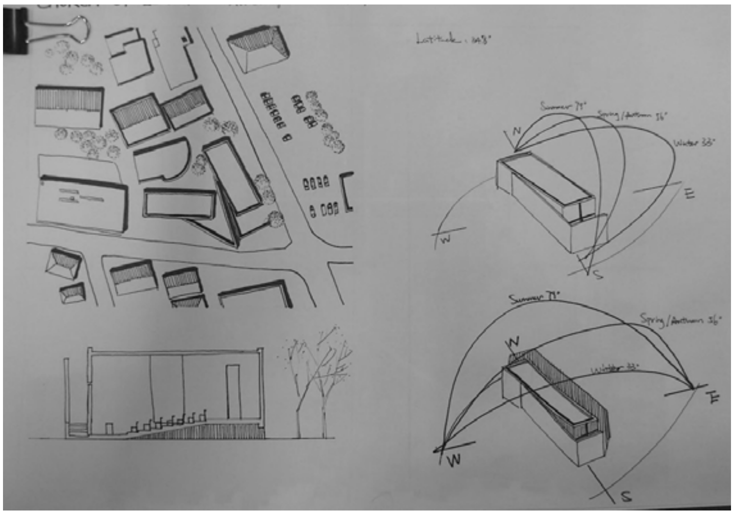


Figure 18 Participant drawing of Church of the Light to determine solar trajectory

Week 7 included an introduction to daylighting/lighting terminology and basic daylighting metric measurements:

- Illuminance
- Luminance
- Daylight Factor (point and average)

After a brief presentation, participants took time to find different methods to measure the lighting in their models using their mobile phone and Texas instruments Sensortag[2] plug-in. It was possible to place a mobile phone within the model and, using the app, record numerical lighting values. Participants were encouraged to use their physical models to explore the changing illuminance and luminance values throughout the space. Spot measurements were taken inside the model and outside and Daylight Factors calculated using Edenapp. Finally, participants were asked to consider within their groups how these numerical results might change as a result of altering the spatial model (volume size, openings and materiality).

[2] The Sensor tag plug-in was developed as part of an additional research project by the Edenapp team to improve accuracy in the use of mobile phones to measure and record results for environmental conditions http://www.edenapp.co.uk/category/lighting.

5.2.2 Pilot Study Workshop – Focus Groups Experiencing Interiors Sketchbook Project Pilot Group A

In week 8, on completion of the pilot studio workshops, focus group sessions were arranged to allow for presentation and discussion of findings from Pilot Group A. Two colleagues were asked to take on the role of focus group facilitators to encourage authentic feedback and reflections about the methods used and learning that had occurred during and after the pilot study studio workshops. Colleagues were chosen for their knowledge of interior design, architecture and environmental design.

Additionally, both were experienced design tutors so were expected to be able to run the focus group successfully. One of the two colleagues had taught some of the participants in a different design class but the other member of staff was unknown to the participant group. Critically, the focus group facilitators were chosen as they were not architectural lighting or daylighting specialists but were still designers who would be empathetic to design processes and vocabularies and the case study buildings would be known to them. Primarily this was to ensure the focus group facilitators did not purposefully or otherwise use specialist or ‘alien’ daylighting terminology as part of their questions or within the discussions unless instigated by the participants.

The focus groups were held in an ante-room off the main design studio space. Video and sound were used to film the focus groups. Cameras were positioned to focus on the central table, to avoid filming faces and allow for any participants choosing to be anonymous to remain so. Participants were given an option of three alternative times to attend the focus groups. Additionally, they were asked to agree the same time as others in the model-making group they had self-selected.

5.3 Pilot Study Workshop – Results Experiencing Interiors Sketchbook Project

Results were first gathered from the colleagues who had taken the role of focus group facilitators. They commented that all participants had been able to complete the tasks to some degree. Participants had worked in groups and it had therefore been difficult to analyse if the creation of the physical models and the subsequent solar trajectory studies had been equally shared among the groups. All workshop participants all took part in the focus group discussions. Each participant offered comments to the discussions although some had significantly more to suggest than others. The transcripts of conversations totalled 2 hours, broken down into shorter group recordings of 10-15 minutes each. Most participants had curated their sketchbooks and had included at least two hand drawn images and an image of the model they had created at the workshops. Two example transcripts are included in the Appendix.

5.3.1 Representing Daylight Visually

It was clear that some had enjoyed the tasks, using the words “relaxing”, “useful but still enjoyable” and “nice to take time to sit and draw”.

Others had particularly liked copying and exploring new drawing techniques. Five participants out of the larger group had used pantone/pro-marker pens to add light and dark contrast. They had layered the pens to define “contrast ratios” (one of the threshold concepts discussed in the presentation of “The Church of the Light”) exploring layering the pen marks to create depth of shadow. As participants started to talk about their drawings as a group in the workshop we discussed the success in the daylighting they were showing. As the discussion had moved on to define “brightness” (subjective) and the idea of “luminance” (measured) “luminance” we decided to test the luminance of the drawings using Photolux app. A set of photos of the drawings were taken using Photolux HDR app and areas of greatest contrast were noted and their luminance measurement recorded. This was only a quick, rough measure (it was not planned or intended to happen in the workshop), but the results of this rapid measurement were intriguing. It was found, on analysis, that the layering of the pen in three drawings equated to a similarity in contrast ratio shown on

Photolux. Although this was a small percentage of drawings tested and selected, the results were still encouraging.

See images below as an example from the workshop:

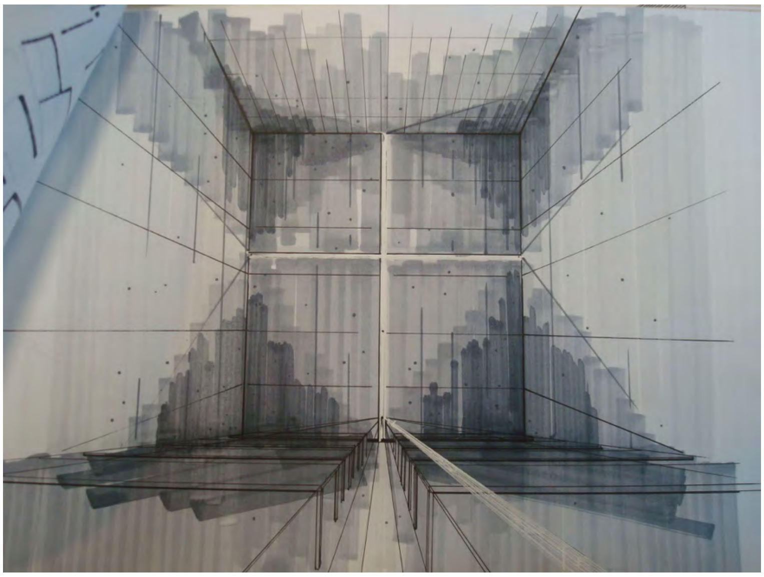


Figure 19 Church of Light drawn with Promarkers "Cool grey 2".

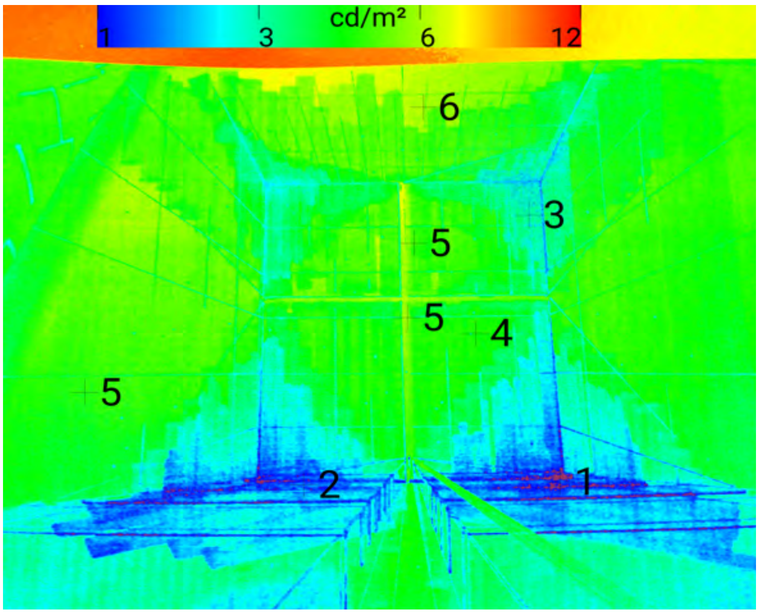


Figure 20 Church of Light drawing Promarkers "Cool grey 2" showing luminance mapping (Photolux).

It was intriguing to see that this concept could be revealed by the participants through using marker pens for depth of shadow. The luminance mapping values cd/m2 therefore provided a relationship e.g. 6 layers of marker = 1 cdm2, 5 layers of marker = 2 cdm2 and so on. This was a fascinating result, particularly because the threshold concept of contrast, as a ratio was demonstrated in this way to the participants. The important concept to understand here was not the layer of pen = an absolute luminance value (as there are too many other factors influencing this) but that the ratio of dark to light could be translated visually to numeric values and vice versa using a scaler method.

Contrast had originally been described in the introductory presentation through the photographs and drawings shown on screen, yet the participants had been able to apply this method in a relatively straightforward manner to the other case studies. This was a clear insight into successfully using technical terminology “luminance” to convey visual ambience.

Other participants used ink or charcoal sticks, applied in layers, to represent the differences in dark and light though the texture some noted was too rough for the walls when the charcoal was applied. Some participants chose to smooth out the charcoal with their fingers to represent the smooth walls of the interior more accurately. The hand drawing techniques allowed the relationships between sunlight, diffuse daylight and shadow to be defined.

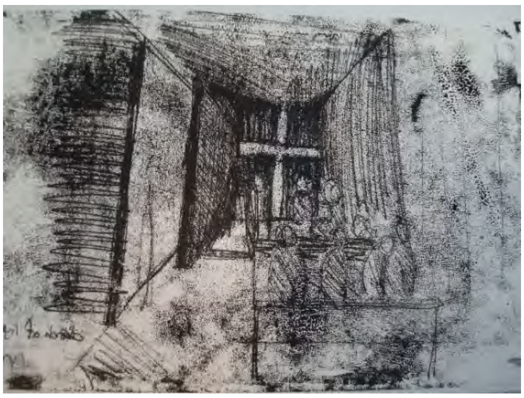


Figure 21 Church of Light - Participant hand drawn output using ink wash

Figure 22 Church of the Light - Participant hand drawn output using charcoal

5.3.2 Representing location and time through daylighting

Few participants had considered the solar trajectory within their drawings. Some said they didn't feel confident discussing (or even guessing) the time of day at which their drawings, showing sunlight and shadow, would be most accurate. The clarity in the participants' definition of the selected daylighting threshold concepts was therefore varied and seen to be successful in an aesthetic articulation of the atmosphere but not understood for the physics of the behaviour of daylight.

Barrett Cleveland, in discussing theatre lighting pedagogy, is shown to be in agreement with the workshop insight, regarding the difficulty in expressing the atmosphere of a space whilst dealing with the challenge of making this an accurate representation of the real physicality of the behaviour of light.

> *Examples of evocative lighting captured in paintings, photographs and other visual media, can help show the essence of a lighting moment…although a valuable tool for communicating the aesthetics one hopes to capture…paintings are not necessarily bound by the laws of physics*
>
> *Barrett Cleveland ((2007) p114.*

However, contrast ratios were demonstrated with some success in the sketchbook drawings suggesting some indication of an engagement with quantitative daylighting aspects.

In the focus groups, participants discussed their self – selected scaled case study models, with some choosing to bring their model to the discussion. Some had images of their models and, although sun trajectories had been discussed and reviewed in the workshop almost all participants commented (by raising a hand and therefore offering a comment) that they still found using the stereographic sunpath difficult. By setting up the models using a new version of Traverso's approach all participants commented that they had found this task valuable though difficult to set up initially to get the angles and heights of the tripods correct. In particular, participants had liked the ease of taking photos on their mobile phones from the tripods and the following week they were able to set up the sun-tracking tripod more easily (most groups were able to help each other). Therefore, the participants' perception of the usefulness and success in the use of the daylighting threshold concept was important to define. In this workshop, using solar trajectory with physical model making as learning methods, participants indicated that it was valuable but not always straightforward to understand the set-up.

However, as an observer of the workshop, it was clear that some participant groups, when engaging with solar geometries, had often forgotten to consider the actual location of the site; building orientation or overshadowing. The participants were working with the Edinburgh latitude and although aiming just to observe it was necessary to intervene at this stage to ensure the task was not misunderstood and learning compromised. Additionally, very few participant groups discussed a location for North or South before testing their model in the artificial sun set-up. The group facilitators found this surprising as the task given clearly demonstrated a strong physical relationship of the sun to the spatial orientation/ model location.

5.3.3 Describing Daylighting Concepts

Additionally, the learning when testing physical scaled models outdoors was less clear. Although shadows became apparent in real sunlight and the notion of the transience of daylight was discovered for many through observation of the changing and shifting patterns, the realisation of sun angles was still challenging. As the participant no longer had a moveable sun (as the sun outdoors was in a relatively static position), this in turn meant that the models then had to be directed at the correct angle to the sun. Subsequently, the logistics and the associated understanding of moving the model ground in relation to the sun was treated as an unfamiliar task. Most groups found this method difficult to comprehend as the ground was effectively no longer in a familiar ground location but raised at an angle.

5.4 Focus groups and analysis

Brief conversational data from the focus groups was entered into NVivo software for analysis. This analysis software allowed some ideas to emerge that could be coded into “technical” and “aesthetic” language through defining these as specific codes when entering each conversational phrase (see Appendix V for full transcripts). These language comparisons of specific words, alluded to a bias in the use of words describing more qualitative descriptors. Pivotal to this study using NVivo as an analysis tool, it was revealed that through a learner’s conversations and language use, not only existing tacit knowledge could be found as they discussed their rationale for design decision making, but these conversations pointed towards the individual’s ontological approach underlying their actions.

However, NVivo was not found to be an appropriate tool to use to identify design protocols or sequential relationships in these conversations or actions. Text frequency, bar charts and word trees did not define these connections in any sequential manner. It was decided that this analysis tool was limiting the analysis of this critical component crucial to the process of learning about daylight. Further investigations were necessary to find a tool to allow the process of design protocols to be coded and challenged successfully.

5.5 Summary of results and insights

Participants found visual representation techniques straightforward, and it was possible for many to expand their representational skills in this area using media that was new to them. For example, participants in the lower years (those who had less experience of design drawing) tried charcoal or ink to demonstrate the spatial design and show contrasting surface developing their awareness of atmospheric spatial drawing created through contrast, sharpness of shadow and sun angles. The participants gave feedback indicating that physical models had helped them in their understanding of daylighting. However, from observing the participants during the workshops and feedback from colleagues/facilitators in focus groups, it was apparent that the clarity of understanding was still not particularly clear when using physical models as orientation and materials were often not considered enough. For example, participants had used card to make the workshop models that was ready to hand rather than checking the colour and texture were appropriate. Through engagement with the creation of the physical models (representing an architectural interior) and moving lights (representing solar trajectories) the participants perhaps showed a false sense of achievement as the concepts being considered were not developed to any depth. It was therefore proposed that a revised workshop to create a physical model combined with a subsequent task of drawing the model's interior would be valuable in exposing relationships with more clarity through repeat observation and comparisons.

Whilst Group A participated in these studies, Group B took part in a single one hour session of daylighting design held in the lab to introduce the participants to working with daylighting within the virtual environment. Details of these workshops now follow.

5.6 Pilot Study Workshop - Introduction Sustainable Daylight VE Study Pilot Group B

For architectural designers; students and practitioners, it requires only basic disciplinary skills to build physical or virtual models, create rendered daylit scenes to convey a particular atmosphere for an architectural space or discuss daylighting ideas through written or verbal means. It is also relatively undemanding to run a set of lighting calculations in a simulated environment using current lighting analysis software further to a brief tutorial (Uduku & Treacy, 2014). However, findings suggest that many architectural designers (both students and practitioners) are unconfident in interpreting these numerical results (see Chapter 3) or perhaps more importantly, verifying that the designed space will look like the designer's rendered visual proposed.

The lab workshop was created to allow participants exposure to current digital software for lighting analysis, challenge the methods they had previously used to evaluate spatial lighting during the field trip and collect empirical data on the misunderstanding or otherwise of lighting software output daylight values. This workshop took place in week 8. Two weeks in advance of the lab workshop participants were asked to create a Sketch-up model of their current environmental design project to use as a basis for the workshop. A digital screen shot booklet was created and loaded to the participants' course intranet site to take participants through the process of creating a sketch-up file for use with the environmental analysis software step-by-step, ready for import. See Appendix V for the workshop notes.

The software selected for the lab workshop was Integrated Environmental Systems Virtual Environment (IES VE)[3] and within this both the Suncast and FlucDI modules were used to focus on sunlight and daylight analysis. IES VE was available within the University campus and I had previous experience of using the programme for full environmental analysis and focussed lighting investigations in design practice and educational settings. Participants attended a short briefing in the lecture theatre to demonstrate the capabilities of the software prior to splitting into smaller, pre-assigned lab groups.

The computer lab was set-up with 12 computer work stations with both Sketch-up and IES VE software. I created follow-along step-by-step exercises and made these available through the course intranet site. The lab workshops allowed for participant groups on rotation, as each larger sub-group repeated the same exercise in smaller groups of 2-3 participants.

A basic template 3D model (in Sketch-up) was created for the use of any participant who did not have their own or a group model to import (see next page).

[3] https://www.iesve.com/software/education

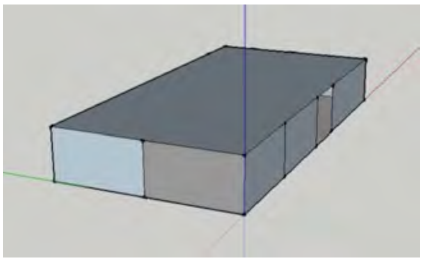


Figure 23 Base model for "Sustainable Daylight VE Study" Group B Pilot Study

5.6.1 Pilot Study Workshop – Tasks Sustainable Daylight VE Study Group B

Participants were encouraged to import the model and follow-along with the commands step-by-step (refer to "IES Import" Workshop notes in Appendix V) demonstrated on a large screen. Each small group selected a location for their model and associated "climate file"[4], checking the orientation and assigning materials to the vertical and horizontal elements. Participants then used Suncast to demonstrate sun and shadow patterning. Finally, participants were expected to "calculate" the daylight and interpret the resulting report, consisting of isolux diagrams, DF and illuminance values (using FluxDl module within IES VE).

Without further individual guidance participants were then asked to return to the import model to make a design change within the building model so as to reduce or increase the Daylight Factor value result. Interpretation of the initial results was therefore tested against the following actions of the participants to understand the factors influencing DF numerical values. Participants then volunteered answers to create a list of factors

[4] For Apache dynamic simulations in IES VE a simulation weather file is required. These files contain data for variables including dry bulb & wet bulb temperature, wind speed & direction, solar altitude & azimuth, cloud cover etc for each hour of the year http://www.iesve.com/support/weatherfiles.

they had found most influential and these were discussed as a group to clarify the most appropriate design decisions.

5.6.2 Researcher's Observations

Participants displayed a mix of cautious and confident attitudes towards learning the new software as no participants had experience of IES VE[5]. As an observer and facilitator of the workshop it was clear that participant groups were able to use the model provided, import it into the software and follow the processes required by Suncalc and FluxDl. Not all understood what the processes implied as they asked questions about what to type in for various parts of the processes. They commented that it was difficult to know what the reflectance values were for the different interior materials, particularly glass as this was not obvious. Due to time constraints and, for some, the unfamiliarity of Sketchup software (required to build the 3D model), only 2 participants offered and provided their own model for the workshop task.

5.6.3 Results

It was important to note that some participants included in their feedback questionnaire that they had struggled to revise the VE model or found the software challenging even although 95% noted in feedback that the worksheets and tutor instruction was "very good". 80% of the student group said they enjoyed learning the new skill with 85% considering it relevant to their subject. However, those that had struggled complained that it was difficult to understand the results of the "calculation", the length of the workshop was too short or that their difficulties had been so great that they had been unable to import their model at all. Some sample answers are listed on the next page.

[5] https://www.iesve.com/software/education

6. How easy was it to understand the daylight factor results the computer calculated for you and could you explain them in your report?

The graph helps alot but it is hard to understand

5. How easy was it to use IES for climate and lighting analysis?

Difficult to start, okay after model worked in programme

6. How easy was it to understand the daylight factor results the computer calculated for you and could you explain them in your report?

I don't feel like it was easy to understand as I didn't have enough knowledge about Calculations to do them correctly.

1. If you used IES for your assignment why was this? ~~If you didn't use IES why was this?~~

Quick and easy way to find out information

2. What problems, if any did you come across using IES?

Software cannot define the room / software freezes while defining the room.

3a. How useful were the on-line worksheets?

Very / Adequately / Not very useful

Figure 23 Sample of participant feedback - IES VE for daylighting.

In order to improve the result for future workshops it was proposed that participants would be allocated groups rather than self-select. As the participants had chosen to form their own groups within the workshop lab participants may have chosen peers that they related well to, perhaps with the same interests, backgrounds and skills as their own. A lack of technological awareness (such as experience with 3D VE modelling or manipulating models) in a group would therefore have been compounded in a group of like-minded individuals and it was considered relevant to address this in any future workshop using digital skills.

5.6.4 Post-it Note Results

Post-it notes were used to bring together participants findings when using IES to demonstrate the multiple ways that a spatial designer can influence the daylighting in a space. Participants were asked what factors they had amended in their virtual model to reduce or increase the DF results. When reviewing the “post-it” note results some groups’ terminology and understanding of the DF threshold concept exceeded my expectations of competency. The words listed were as follows:

Element to Change	No. of Groups with Proposed Solution to Change DF% Numerical Value
Change my windows (bigger, more windows, bigger glazed wall or similar)	6
Floor (change it)	5
Make the walls lighter or darker (or similar)	5
Roof lights	3
Use mirrors but didn’t know reflectance	1
Make the ceiling white	1

Change outside illuminance	1
Take wall away and change to glass	1
Birch to dark fired ash (specific material change) Roof lights	1

Figure 14 Group B workshop participants' responses to model amendments in IES VE affecting DF output ("post-it").

The groups' answers to the "post–it" note discussion provided evidence of very subtle (and therefore deep) understanding of the concept demonstrated in their answers pertaining to reflectance values of the spatial surface materials, even going so far as to the real material choice that would provide this eg. "birch" replaced with "dark-fired ash".

Others had become disengaged and had apparently used the software in the workshop in the most minimal possible way, offering only the most obvious "post-it" factor influencing a change in DF, to "increase the window size". Although this demonstrates an understanding of the DF result being a relationship of inside to outside illuminance, it shows a quick, shallow solution to the problem they were tasked with. This result aligns closely with the result that Ahmed (2003) found in his studies within engineering design student groups of novices and final year students. Novice students used a 'trial and error' technique for generating and implementing a design modification. This was often the first and most obvious idea. In this research study, those participants that were able to clarify the chosen reflectance of materials made a difference to the resulting DF and were able to suggest a material to achieve this with not only demonstrated a successful trial and error approach but, crucially employed an integrated design strategy and holistic spatial thinking.

5.7 Pilot Study Workshop – Introduction Sustainable Daylight Field Study Pilot Groups A + B

Both participant groups took part in the field trip study. Group A spent a single morning attending a presentation and then an hour on site as a single group together. Group B had two separate sessions of tutorials related to daylighting and sunlight analysis within their semester long (11 weeks) environmental design course. Both groups were separately given a half hour presentation on daylight and sunlight which included an introduction to measuring illuminance, Daylight Factor, the "no sky line"[6] rule of thumb (Peter Tregenza, 2014) as shown below, and solar trajectory.

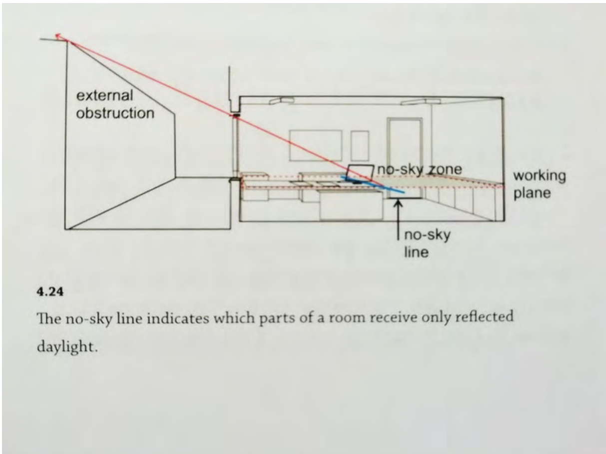


Figure 25 The "no-sky line" diagram (P Tregenza & Wilson, 2011), p. 91.

For Group B this session was followed by workshop tasks in the lecture theatre space using the stereographic sunpath chart for Edinburgh and a nomen study [Brown, 2001, Sun`, wind & light : architectural design strategies], p. 5., using a miniature building block (a Monopoly playing piece hotel) and mobile phone light . The following week Group B participants attended a talk about their case study space, the University of Edinburgh Catholic Chaplaincy Chapel (St Albert the Great), given by the Client and user of the case study building. He introduced them to the design brief he had created for the architects of the building and discussed the building of the space and

6 The no-sky line marks the boundary of the area in a room that does not receive light directly from the sky.

the use of the space that he enjoys every day. He talked about the light, materials and activities of the people who inhabit and visit the space. Group B then visited the space in sub-groups the same afternoon.

5.7.1 Pilot Study Workshop – Tasks
Sustainable Daylight Field Study
Pilot Groups A + B

Participants were then given tasks to carry out when they visited the space. Prior to the visit they were asked to bring drawing equipment and load "Edenapp" on to their mobile phones if possible. Group B were split into groups and visited the University of Edinburgh Chaplaincy Chapel on a timetabled rotation during the afternoon to ensure everyone had time and space to explore and experience the building inside and out. Participants were all given a set of dimensioned plans and sections in a printed workshop booklet. The following tasks were included:

- Draw the light in the space, using black or grey paper/card as a background and use chalk or light pencil to draw in the light/lighting contrast.
- Define areas on plan where the sky is no longer visible. This can be done by sitting in different pews, noting the location on plan and drawing the boundary at which the sky can no longer be seen. A physical experience of the "no sky line" rule of thumb.
- Calculate the average Daylight Factor using the formula page and spatial dimensions and reflectances given.
- Calculate point Daylight Factor values using Edenapp. Work as pairs for this task and group together with participants with the mobile phone app (Edenapp), taking turns to use the light sensor plug-in.

2 no. University mobile devices and 4 no. plug-in light Texas instruments sensortags were supplied to ensure all participants were able to fully participate. Participants spent up to one hour on site completing the tasks. During Group A's visit and Group B's visit the sky was overcast, so coincidentally appropriate for daylighting measurements for DF, though not as effective for drawing sunlight and shadows.

5.7.2 Pilot Study Workshop – Design Staff Observations Sustainable Daylight Field Study Groups A + B

Participants were able to ask questions and ask for guidance to complete the tasks if they wished. Each workshop on rotation had the same staff as workshop facilitators; the researcher and two design tutor colleagues who were environmental design specialists. These colleagues had attended the previous lecture on daylight and the talk and had a briefing session prior to the site visit.

Further to the visit the colleagues were asked for feedback on the tasks:

- Had the participants been able to complete these tasks? Independently? With help?
- Which tasks had generated most discussion?
- Had any tasks not worked well?
- Had any participants commented on the tasks or the methods used?

5.7.3 Pilot Study Workshop – Participant Feedback Sustainable Daylight Field Study Pilot Group A + B

It was not possible to timetable focus group sessions into the workshops due to time constraints of the participant Group B. However, regularly, the participants as a year group are asked to take part in an online, self-assessed quiz as part of their environmental design course in week 10 of the semester each year. This quiz is not part of any formal assessment. As part of this study, using this opportunity for feedback, prior to the quiz, participants were asked to fill in an anonymous online questionnaire regarding feedback about the methods and tools used during the course generally (see Appendix). Feedback was limited on this but comments noted a difficulty in importing models, they enjoyed using Edenapp but wished for it to do more than measure Daylight Factor.

5.8 Pilot Study Workshop - Results and Insights Sustainable Daylight Field Study

Observations from colleagues for this workshop were particularly enlightening as some of the workshop facilitators had received only basic training in daylighting calculations and the use of Edenapp prior to the start of the first workshop. Firstly, colleagues noticed that participants discussed with others in order to complete the tasks (colleagues had done so themselves), and, as they were numbered tasks the participants had assumed they had to be followed sequentially, this was incorrect. This scenario was further discussed with colleagues and I proposed that for further workshops the tasks would be outlined in cards that participant groups would select in a random order to complete to ensure that participants were spread out throughout the space and not all completing the same task at once in the same part of the space. This was also proposed as a solution to only a few workshop participants completing the tasks and the other groups simply copying the solutions step by step and not engaging in the workshops.

On the whole, results from the field trip workshop identified the knowledge domains within which the selected threshold concepts were positioned as very disconnected. As each task demanded focus for the exploration of a specific threshold concept this demonstrated a detrimental effect to the full holistic overview of the daylight in the space. Participants commented that they found the DF hand calculation easy to do but had not realised they were using the same daylighting concept when measuring DF with Edenapp. Responses in the questionnaire noted that Edenapp had worked well to describe the relationship of internal illuminance to external illuminance.

However, colleagues had noted that they and the participants, whilst calculating the DF value by hand or using Edenapp, they had no clear association with the "no-sky line" sketches the participants had been asked to produce as one of the other tasks. Additionally, the colleagues and participants had incurred problems when they tried to define the "angle subtended to the sky", see (P Tregenza & Wilson, 2011), p. 212. These differing methods of calculation clearly have a relationship with spatial volume and depth in relation to proximity to windows but this connection was not made. These connections were not immediately apparent to the participants I suggest because the tasks were numbered separately and perhaps lacked reflective questioning of these relative values, making connections less obvious to find.

In almost every case the participants preferred to discuss their drawing and the process of observing and drawing the light, not the process of the calculation. For the calculations, only the answer was seen to be important. Again, it was only when questioned further that the participants understood the importance of the variable they had input into the calculations. It was not clear that these connections had been made and the methods had therefore not clearly assisted relational understanding..

5.9 Summary of pilot workshop results and insights for further study

It was found that the use of varied learning methods, both qualitative and quantitative, could be explored satisfactorily in the workshops as participants were able to carry out the tasks. However, it was clear that these individual workshops and/or tasks lacked continuity and an opportunity to reveal ontological connections between the daylighting concepts.

Findings in relation to the lack of connections that participants demonstrated in their discussions and through colleagues' observations, challenged the use of different case studies for different methods and clarified the need for rigour in the selection of case studies for any further research. Although participants were able to represent daylighting successfully, clarity in the understanding of the threshold concepts was not consistently apparent. Any case studies were therefore required to be appropriate for varied processes and, ideally visiting and for building 3D models physically and virtually in order to provide the best opportunities for connected and integrated learning.

It was found that the idea of Constructivist "situated" (Brown, Collins, & Duguid, 1989), learning was not tested fully in the Pilot Study Workshops, for example, the case study used for virtual environment analysis was not a building that was used in other workshops or a spatial design that was familiar to the participants.

Although the participants found the IES software "useful" in their search for numerical values (in comparison to hand calculation procedures), the difficulty in the terminology demanded by the software and the required numerical inputs was challenging. It was therefore proposed to introduce a case study model in the revised workshops that would allow the context to be more clearly understood, for example, through experiencing a visit to the building in person prior to the IES workshop and subsequently re-visiting this case study for the participants' solar trajectory studies workshop for example.

Cross (2011, p105) notes that "Concepts need to be built up, with additions and variations being developed to turn the initial idea into something more robust" (Cross, 2011) p. 105. Although in this instance Cross is referring to creating and testing a new design concept, it is proposed that our understanding of a threshold concept and its application in a new context can be viewed in a similar way. Through basic understanding of the threshold concept we have loose connections to other design contexts. However, as additional connections are made and subtle variations understood we can start to apply this threshold concept in a more robust way in increasingly complex situations.

Qualitative or quantitative tasks were presented sequentially in the pilot study workshops. Although considered useful by participants and colleagues, the methods used in the workshops did little to assist in the understanding of the complex, "capricious" (Rasmussen, 1964) nature of daylighting. Each characteristic of daylight was presented and observed as a distinct phenomenon, rather than as an integral dual approach, considering both quantitative and qualitative representations simultaneously. Therefore, although the pilot studies sought to and successfully demonstrated, a localised discovery of the behaviour of light through most tasks, the understanding of the relationships between the visual and reciprocal numerical measure required for parallel processing was less clear using these methods and required further explorations.

Rather than exploring further diverse methods for daylighting, it was proposed to allow for the methods to overlap and therefore seek to provide a more robust understanding of each daylighting concept. It was considered important to explore this further in a set of revised workshops to address these issues. These workshops would be re-designed to test the findings from the pilot study workshops and develop this new methodological approach for daylighting pedagogy. It was determined that methods to embrace both quantitative and qualitative aspects of daylighting concepts together, developed through the design task activities were worth exploring. Rather than typical sequential ordering or separation of daylighting tasks as demonstrated by the pilot studies (and the pedagogical approaches found during the review of literature), a full immersion for participants into the design thinking of a new, ‘dual-ontology’ for daylight was proposed. In this way existing pedagogical methodologies were challenged through uniting, rather than separating current qualitative and quantitative ontologies in relation to daylight in spatial design contexts.

Chapter 6 Research Procedures – Main Study

6.1 Introduction to workshop methods for a dual-ontological approach for daylighting through: ‘see’ing, ‘touch’ing, ‘record’ing

In order to realise a new, ‘dual-ontological’ approach for the teaching and learning of daylight, new pedagogical methods were developed. This required redefining the pilot study workshop tasks, ‘threshold concepts’ and case study selection. A new set of workshops exploring qualitative and quantitative ontologies for daylight using “dual” (integrated) and approaches within selected spatial design contexts was proposed and trialled. New interventions were proposed to: (1) address the challenge of exploring, testing and advancing dual- ontological approaches for daylighting, (2) assist in defining any learning, if any, from these integrated methods (visual and/or numerical) and (3) test the use experiential “designerly ways of knowing” (2006) to encourage more engagement with the workshop tasks and use in future design scenarios.

Findings from the literature review in relation to the differing ontological perspectives of daylight were reviewed again to inform the workshops methods, advancing the methodology of the pilot study workshops. Giddens (1991), in writing about reflexivity highlights that experiential responses are continual. We continue to develop our experiences through exposure to new conditions and in our reflections of past experiences. This can be understood to help reveal the subjective cultural position we might hold both ontologically and epistemologically. In this thesis therefore, the inclusion of reflexivity in design processes within workshops implies an aspiration for the participants and researcher to heighten the awareness of an alteration of our own perspectives, through revealing our previous position, whilst influencing our future understanding and integration of new concepts. It is proposed that methods that encourage this reflection explicitly, on a regular basis, with the recording of these events for future analysis, develops a positive methodology for the learning of design and exposing and advancing the tacit assumptions of specialist fields such as daylighting. It was suggested that throughout the workshops, participants would not be simply observing the scene, but engaging with it as they developed responses to the tasks and reflected upon them, learning an indispensable skill Gustina described as learning to 'see' (2011).

In Chapters 3 and 5 this thesis has shown that the majority of spatial designers' previous and continuing experiential learning has had a direct influence on their qualitative ontologies that they hold for daylight through visual approaches. It has been outlined that a designers' education, design practice and CoP, has a significant influence on spatial designers' ontological and associated epistemic perspective of daylighting.

It was therefore proposed to base learning tasks on these experiential "designerly ways of knowing" (Cross, 2006) approaches; physical drawing and model making, creation of drawn or photographic visuals, whilst building in less obvious, but nonetheless important, quantitative technical measures such as lighting measurement tools in virtual environment software and graphical contrast scales or apps.

For the new proposed workshop set it was important to ensure that participants could engage with quantitative and qualitative ontologies with ease, using and understanding the proposed integrated "dual" methods successfully. With reference to the literature review discussing the diverse Communities of Practice interacting with daylighting design, the purpose and value of daylighting outputs varied significantly. The differing ontologies for daylight examined in the literature review highlighted distinct visual or numeric methods and outputs possible.

For some CoPs, visual qualitative outputs revealed experiential atmospheres. For others, numerical outputs measured the quantity of light for tasks, defined exposure of occupants or objects or energy demands. Although the pilot studies had included tasks that invited participants to measure the daylight in the case study spaces they had built in the workshops using Photolux[1], it was perhaps not made fully clear how these measures could sit alongside the visual representation of that space, other than a brief discussion with the group. Any new methods explored had to address this to ensure relational aspects were obvious. These findings therefore underlined the

[1] Description of Photolux - Photolux for Android is a limited version of Photolux for PC developed by LGCB, a research laboratory, located at ENTPE (Vaulx en Velin, France). http://www.photolux-luminance.com/index.php.

challenge of presenting a combined perspective for daylight through workshop methods.

It was therefore proposed that through engagement with 'dual', integrated methods to understand the ontological (and assumed epistemological) rationale for these distinct daylighting perspectives, it would be possible to understand each for their benefit within the wider field of spatial design. It was proposed that theoretically and practically a dual, reflexive, approach would be appropriate for achieving this. It was decided to include tasks within the workshops requiring daylighting information to be presented as overlays where possible, to allow and encourage simultaneous assimilation and synthesis of outputs. Where the specific tasks did not permit this type of simultaneous representation of information and experience, this was approached using tasks demanding rapid iterative processes to encourage referring back to previous outputs, still seeking to promote a relational, reflexive approach.

Pedagogical approaches from other fields as discussed in Chapter 2B, revealed the experiential possibilities that had not been used to their full potential within the pilot study tasks. Participants had discussed how they had gained from their "experiences" in the pilot study workshops and although in some cases this was not as significant for some than for others, the methodological approach was understood to be successful. Therefore, in the methods selected for the main study, the experiential learning potential was maximised and reflection of these experiences encouraged. The use of various formats such as drawing, model making and digital 3D modelling are known to encourage the acquisition of experience to some degree. Further, the notion of engaging physically and reflecting on the experience is known to encourage designers to "think and feel in response to [one's] own luminous and chromatic world" (Tregenza & Wilson, 2011) p. 57., an objective, matching that of the research study workshops.

Therefore, this chapter sets out the main study workshops, seeking to highlight where and how a 'dual-ontological approach' to daylighting could be adopted within daylighting design pedagogy. It does not outline a completed set of stand-alone workshops. Rather, it introduces a set of workshops based on a specific methodological approach, that can adapt the methods used within it, to align with evolving daylighting metrics and emerging design agendas. It seeks to outline a methodological approach that is repeatable but is also adaptable to suit different future contexts as required.

6.1.1 Introduction to experiential methods and aligned methodologies for workshops: ‘see’ing, ‘touch’ing, ‘record’ing

In the Pilot Study Workshops key questions had been asked in relation to the threshold concepts identified (Refer to Chapter 4 for full explanation):

1. **What are the dynamic characteristics of daylight (physically and numerically)?**
2. **How can the relationships between sunlight, diffuse daylight and shadow be defined?**
3. **How can we propose an internal daylighting condition for a space through knowing the sky conditions filtered by the formal architectural envelope (physically and numerically)?**

Pilot Study Workshop findings confirmed the need for providing *relational,* ‘threshold concepts’. The workshop findings also clarified the need to demonstrate these concepts to participants as *relational*, theoretically and practically. In the Pilot Study Workshops, participants’ engagement with ‘threshold concepts’ had been less successful when relational contexts had not been emphasised within the nature of the workshop tasks (when using IES VE for example). Where the relational values had been demonstrated, participants had shown some understanding of the usefulness of the concept within the larger remit of the spatial design process through their language use and subsequent actions.

Similarly, the Learning Objectives used for the Pilot Study Workshops, as outlined in Chapter 5; 1) “to represent the ambience of a lit architectural space”, 2) “to predict the effect that daylight will have on an architectural space” and 3) “to describe daylighting concepts”, needed a more relational approach to the methods used to achieve them. To explore these ideas further, and find practical applications of this approach, it was decided to further consider the pedagogical methodologies proposed and discussed in Chapter 4 and 5.

> *My experience in teaching at several universities these past 40+ years has proven to me that most of the students who came to learn lighting had never first learned to see... it seemed they had no power of observation... it was simply that no one had taught them "to see"… disciplined observations of light will build "a databank of real knowledge which can serve in any capacity as we design our lives.*
>
> *(Brandston, 2009)*

Brandston's work in architectural lighting is nationally and internationally known and his teaching methodologies endorse methods that encourage designers to 'see' rather than "look" (observe) [at] lighting within spatial design. He suggests that if we "see to understand" a designed space we start to notice "clues" that allow us to know, "how to design what it is you wish to see" (Brandston, 2009).

6.1.2 'see'ing

The workshop tasks implied that 'see'ing light involved examining closely abstract lighting principles through *describing* relationships between daylight and the spatial environment e.g. the sun location relating to the sun and shadow patterning of interior space. Workshop tasks that involved 'see'ing light were set as individual requirements to allow reflection on each designer's own understanding and epistemic alignment. These were then developed into collaborative group work, to allow reflection of each designer's own intentions and understanding against others. This 'see'ing was supported through learning to 'see' daylighting through different formats and measures such as photographic visuals, drawn representations of architectural spaces, or 'see'ing and therefore experiencing changing numerical values dependent on the circumstances and settings.

6.1.3 'touch'ing

Modelling workshop tasks were primarily set as collaborative group work to ensure the tasks were not too onerous on participants. The tasks set considered manipulating variables in lit environments through heuristic discovery: a hands on drawing approach (Pallasmaa, 2009) and physical and virtual environment model-making challenge to define daylight *affecting* the spaces of study through the direction and proximity of daylight interacting with the material, volumetric and colour boundaries. Vasseleu (2010) presents the texture of light as a fabric in which 'touch'ing is always implicated in vision, and vice versa. In the workshops these relationships between manipulating models (physical or virtual) and experiencing the outcome of these manipulations was considered important to support this methodology of 'touch'ing.

With this in mind, the tasks implied that 'touch'ing light involved *manipulating* visible relationships between daylight and the spatial environment to reveal abstract daylighting threshold concepts (qualitative and quantitative) in a material context. Through three dimensional, heuristic learning methods and associated formats for expression, it was imagined that participants would indeed learn to 'touch' light tempted by the invitation to explore and investigate lit space.

6.1.4 'record'ing

The idea to invite participants to learn about daylighting through 'record'ing their actions and outputs was formulated from the sketchbooks produced in the Pilot Study Workshops. The methodological support for this is outlined in this section.

Initial ideas for the creation of a daylighting lexicon were developed from various fields where the realisation of a design concept/behaviour/structure was acknowledged to be difficult to define due to complexities in material selection and/or the integration or application in varied scenarios. The most influential of these sources are outlined in the next section.

6.1.5 Rowe's lexicon of metal "recipes"

Books such as Hughes and Rowe's, "The colouring, Bronzing and Patination of Metals" (1982), successfully creates a visual lexicon, a source for fine metalworkers to refer to, to formulate a desired outcome through practical application of the processes outlined.

Recipes are described as 'not recommended' if they proved to be particularly intractable in tests, and are likely to be problematic in colouring objects. Those recipes, on the other hand, which readily produced consistently good *results are marked with an asterisk*. This book seeks to give ideas of the "potential" for the artist craftsman, encourages exploration through demonstration of successful applications and as such becomes a valuable tool within the field.*

(Hughes & Rowe, 1982)

2.111* Blue-green patina on pale brown ground Semi-matt/matt *Pl. IV*

Ammonium chloride	35 gm
Copper acetate	20 gm
Water	1 litre

Cold application (Several days)

The ingredients are ground with a little of the water using a pestle and mortar, and then added to the remaining water. The solution is applied to the object by dabbing and wiping, using a soft cloth. Application should be sparing, to leave an evenly moist surface. The object is then allowed to dry in air. This procedure is repeated once a day for several days, producing a gradual development of the ground colour and blue-green patina. When treatment is complete, the object should be left to dry for several days, during which time there is further patina development. When completely dry, and surface change has ceased, the object is wax finished.

There is greater development of a more intense blue-green patina on rough and as-cast surfaces.

It is essential to ensure that all patina development is complete, and the surface is completely dry, before wax finishing is carried out. The final drying period may have to be extended to a matter of weeks in damp or humid conditions.

Figure 26 Example "recipe" from (Hughes & Rowe, 1982)

Collins (2010), through a Constructivist lens would describe this book of recipes as expounding, relational tacit knowledge, a type of tacit knowledge that can be passed on through description of processes in order to achieve a desired outcome.

6.1.6 Di Mari and Yoo's "Conditional" and "Operative" lexicon

Within the field of spatial design examples also exist in relation to Di Mari and Yoo's books 'Conditional Design' (Anthony Di Mari, 2014) and 'Operative Design' (2013). These books create a guide for spatial designers with spatial heuristics, defining design moves that would otherwise be tacit considerations and rarely revealed. The verbs contained in this book are organised within a systematic framework to begin to differentiate how they operate space volumetrically. The categories set up in the table of contents are meant to “initiate spatial opportunities rather than to limit them” (A Di Mari & Yoo, 2013). This ‘lexicon’ introduces the designer to the possibility of understanding spatial formation as a process that can be derived from heuristic actions, defining starting points for the creation of space and also implying an important relationship between the individual designer and the space created.

These books transformed my understanding of heuristics in spatial design as the spatial descriptors used suggested possible paths into the creation of heuristics that could guide daylighting design decisions. Yoo and Di Mari’s spatial verbs animated the elemental components to create design moves, demonstrated in realised projects. Yoo and Di Mari have commented that through using their “Catalog of spatial verbs”, architecture students were able to “translate their conceptual ideas and ‘everyday’ observations into the new spatial language of architecture they were just beginning to learn” (Anthony Di Mari, 2014) .

Again, although this source originated from within the field of spatial design this resource provided descriptive and visual heuristics specifying design intent and expected behaviours of the elements the designer is engaging with.

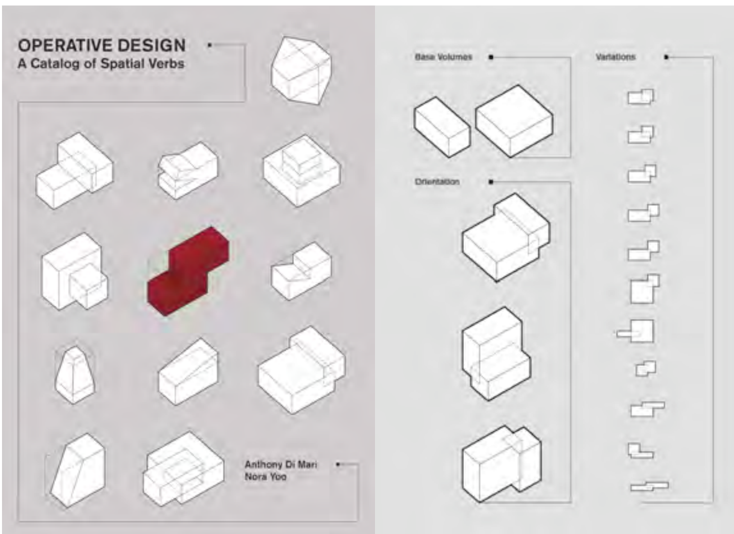
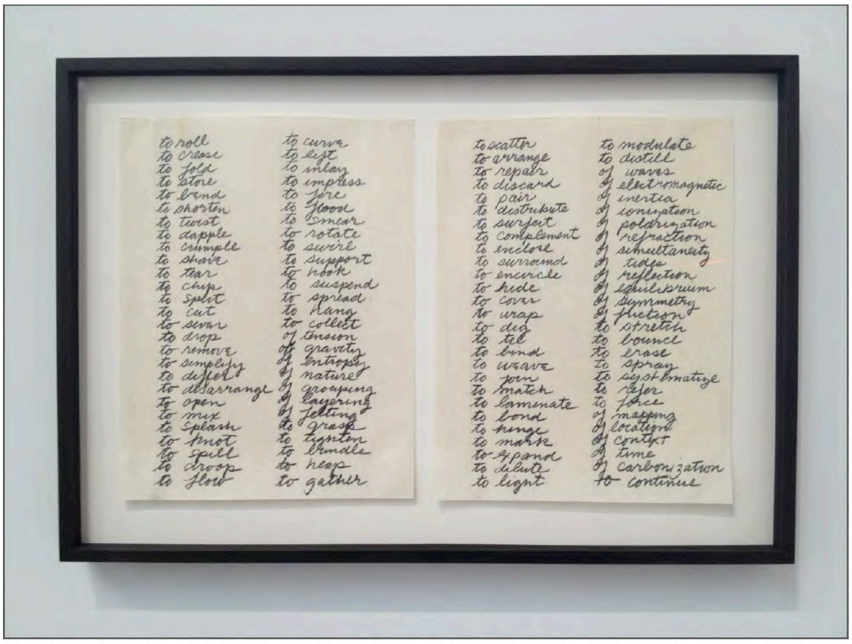


Figure 17 Operative Design (A Di Mari & Yoo, 2013)

6.1.7 Serra's "Verblist" as lexicon

Richard Serra's "Verb List Compilation: Actions to Relate to Oneself" 1967-1968 works in a similar way, showing how language can invoke form, as well as one's experience or interaction with it. In Verblist, Serra compiled a series of what he called "actions to relate to oneself, material, place, and process" (Serra).



Richard Serra, *Verb List*, 1967, graphite on paper, 2 sheets, each 10 x 8 1/2 inches (25.4 x 21.6 cm). The Museum of Modern Art, New York.

Figure 28 Serra's "Verblist", MOMA, (1967)

His list, which includes 'to light,' 'to flood,' 'of context,' 'of time,' balances what can be read as a systematic approach along with its effect on the consideration of spatial character, and, in some instances, the "thingness of light" (Holl, 2000). The list is at once "defined and yet limitless in what it could yield formally and experientially" (Serra) This source exemplifies the personal or distinctive nature of an artist's approach to varying conditions, yet epistemologically, this approach would also align with that of a spatial designer working with daylight. Within lighting, the need for translation of concepts is critical, to clarify design decision making and in the creation of a representation of a design concept that can be understood by others. The importance of this personal, yet universal language was considered key to the success of this lexicon method.

6.1.8 Moholy Nagy’s Light Modulator Lexicon

Few detailed directions are necessary for the actual making of the light modulators. Each is the product of the individual’s own ingenuity, dexterity and interests. Having seen in the accompanying illustrations what some typical light modulators have been, you can imagine what any other modulator might be…Observe closely. Impress upon your memory the manner in which each feature modulates the light.

(Kostelanetz & Moholy-Nagy, 1971)

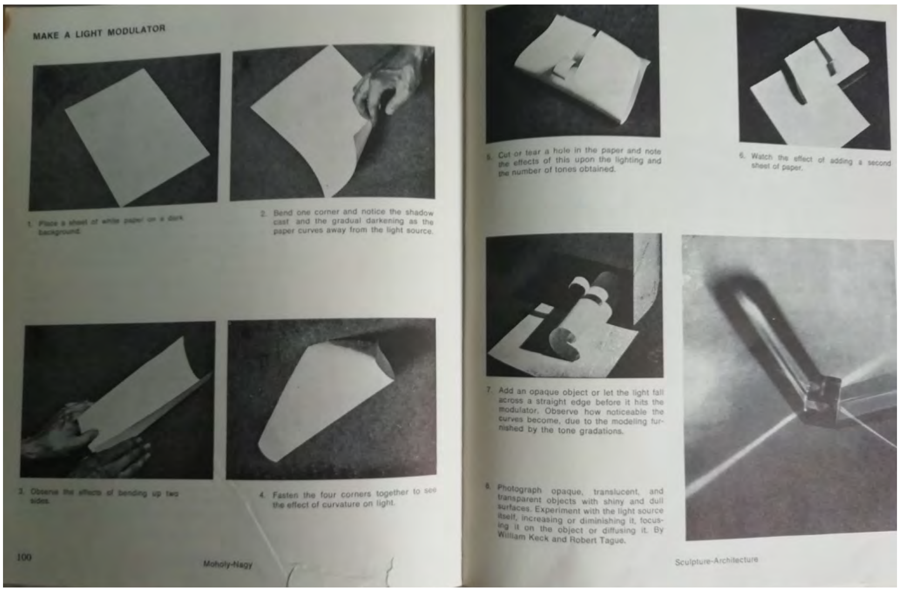


Figure 29 Lightspace Modulator, Moholy-Nagy (1940)

Moholy Nagy’s principles for his “Light space modulator” (1940) experimentations grew out of his Constructivist approach to art and design teaching. As an artist photographer, painter, sculptor and photographer, his experimental approach developed connections between the artefact and the technology used. His “light space modulator” exercise for students at the Bauhaus school of design advocated first for students to note their “emotional reactions” (1971), p. 103, to the models they developed and for the use of photography to see new perspectives of artefacts that the eye could not.

Although this exercise investigated photographic techniques that were to be used in the domain of portrait photography, the idea he demonstrated was seen to be relevant for this study. An observational technique to “see” light and record it through another lens to enhance alternative perspectives of the same scene was considered useful, and supported a multi-modal approach to learning. Additionally, his focus on students observing their emotional understanding of the physically developed model (although sculptural and not spatially positioned or scaled) was also significant and an issue that was discussed in the workshop explorations.

6.1.9 Workshop methods: ‘see’ing, ‘touch’ing, ‘record’ing

Tasks for ‘record’ing daylight were therefore centred around an individual lexicon sketchbook with recording added each week, defining a reflexive learning log. All other ‘record’ing tasks were set as small group work activities to ensure materials were available for all participants, encourage explicit decision making and shared translations through reflexive discussion. The tasks set considered recording lit environments through heuristic discovery: a personal/group scalar graphical method to define daylight ‘quantities’ and ‘qualities’ (see worksheet week 1) and an exploration of a real daylighting case study (on-site, see worksheet week 2), physical scaled models of selected case study buildings (see workshop 3), virtual daylight modelling (using computer software see workshop 4/5 worksheet) with associated, selected metrics, introduced in conjunction with these activities. These tasks implied that ‘record’ing light involved *translating* absolute and relational (rule of thumb or metric based) numeric daylight values through varying formats to reveal abstract daylighting principles as an understood, matching, visual presentation.

As conversation analysis was taking place it was considered useful to collect daylighting language through heuristics used by participants in the workshops and collate these. Further to developing a list of heuristics extracted from the conversation analysis from the participants, it was expected that participants might demonstrate some alignment with these findings from the workshops in their Lexicon sketchbooks.

It was planned to hold workshops on a weekly basis when possible to encourage continuity and increasing depth in the study of daylighting. Protocol recording was explored to examine design process through design tasks as they progressed during the workshop sessions. Design protocol recording is known to be, “an observational research method for the analysis of design activity” (Cross, 2011). However, in order to ensure processes were not interrupted, the explorations in the studio setting were sound recordings only, without digital visual recording.

This experimental set-up was expected to become a familiar one as the workshops progressed on a weekly basis. It was understood to be critical for this study that the workshops were not, “laboratory protocol study experiments that were in many senses far removed from the reality of everyday design practice” (Cross, 2011), p. 115, therefore, weekly sound recordings without significant photographic or filming interventions was expected to reassure participants, and the familiarity of the situation would encourage authentic behaviours.

All photographic stills were taken by the workshop participants as they carried out the workshop tasks other than stills taken from focus group film footage. Participants were asked to carry this out routinely at regular time intervals to reduce anxiety or halt on-going discussions and held as a basic record of the workshop event or to capture any significant outputs such as models, drawings or results of experimental set-up.

A summary of this experiential methodology is outlined as follows:

> Visual, explicit verbal – Learning to ‘see’
> +
> Heuristic, explicit action, model or drawing or numeric manipulation – Learning to ‘touch’
> +
> Reflexive translations – Learning to ‘record’
> =
>
> Enhanced opportunities for participants to engage with daylight in spatial design.

The first workshops introduced participants to daylighting vocabulary and selected visual sources to reflect on individually, and discuss in small groups (see workshop 1 notes and “selected visual images section”). In the middle weeks of the workshop set, participants, using this vocabulary to understand the tasks, sought to measure and evaluate the lit ambiance of a physical and virtual spatial model photometrically. The models were from the selected visual studies from week 1 and created in small groups. Quantitative analysis was then repeated using each group’s physical model measuring DF, illuminance and luminance with Edenapp and Photolux apps on mobile phones placed within or against the physical model. These workshops demanded physical model making and manipulation to encourage haptic engagement with lighting metrics.

The final workshops asked for revisions to both proposals, the 3-dimensional virtual model and the 3-dimensional physical model. Participants were asked to revise and manipulate the models physically and virtually to comply with a given 4% daylight factor and an average illuminance of 200 Lux over the working plane as an example level requested by local building regulations.

In the next sections of this thesis, the Reflexive Threshold Concept Questions that determined the tasks set for the workshop participants are listed alongside the task descriptions for clarity in understanding of research approach only. Participants were not given these questions at the beginning of the workshop to avoid specific approaches to find quick answers to the questions posed, rather than fully exploring the potential of the concepts within the tasks. Within each workshop the Reflexive Threshold Concept Questions were discussed as the tasks progressed with all reviewed at the end of each workshop and in weeks 7 and 8 during the focus group discussions. The workshop programme was as follows:

	Workshop Group A (Interiors)	**Workshop Group B** (Architecture)	**Workshop Group C** (Interiors)
Workshop 1 Describe	- Describe visual - Re-describe visual (in group) - Hand draw visual - Measure visual with Photolux - Start Visual Lexicon		- Describe visual - Re-describe visual (in group) - Hand draw visual - Measure visual with Photolux - Start Visual Lexicon
Workshop 2 Field Visit	- Presentation by Client - Hand drawing of space - Measure absolute values (no skyline) - DF hand calculation - DF Eden App - Photolux contrast measure	- Presentation by Client - Hand drawing of space - Measure absolute values (no skyline) - DF hand calculation - DF Eden App - Photolux contrast measure	- Presentation by Client - Hand drawing of space - Measure absolute values (no skyline) - DF hand calculation - DF Eden App - Photolux contrast measure
Workshop 3 Create Model: Studio	- Make mode from previous drawing (given by other group) - Set up sun path - Using physical model and location to test sunpath and create matching interior effect - Continue Visual Lexicon		- Make model from photograph - set up sunpath - using physical model and location to test sunpath and create matching interior effect - Continue Visual Lexicon
Workshop 4 Model: Studio	- Manipulate physical models to comply - Measure and record DF, luminance contrast - Re-draw from model or photographs - Continue Visual Lexicon		- Manipulate physical models to comply - Measure and record DF, luminance contrast - Re-draw from model or photographs - Continue Visual Lexicon
Workshop 5 Model: VE	- Import 'field visit' model from SketchUp - Measure DF (Flucs DL) - Test sunlight (suncast) paterning - Compare with visit - Re-model to suit given DF		
Workshop 6 Visual Lexicon	- Re-describe lighting 'threshold concepts', haptic heuristics and/or daylight terminology		- Re-describe lighting 'threshold concepts', haptic heuristics and/or daylight terminology
Workshop 7 Focus Group	- Reflections on workshops - Review of outputs		- Reflections on lexicons - Re-describe image from Workshop 1 'Describe'
Workshop 8 Feedback		Completion of an on-line questionnaire	

Figure 30 Main Research workshop matrix including participant groupings.

6.2 Participant Groups

Three participant groups took part on the main research study. For the main research study, as it was consecutively built upon over two academic year periods 2016/17 and 2017/18, Groups B and C were formed of the same core years of spatial design training as used for the pilot studies, but the participants were therefore taken from a new student cohort each time. Group A remained, for the majority, the same group of participants with new participants joining the lower years of the course and those completing leaving the group:

- **Group A** – A mixed group of design novices ranging from 1st year Interior design students with less experience up to Masters level Interior design students, some with design work experience, with different nationalities and design educational backgrounds.
- **Group B** - created from a larger architecture year 2 student cohort. This larger group was split into smaller groups for digital lab work and field trips. These participants only took part in Workshops Type 2 and 4 due to time constraints and curriculum demands.
- **Group C** - 3rd year Interior design students ranging in nationality and design educational background.

Participants were asked to work in teams of three in the workshops, necessitating verbal communication between group members to discuss and carry out the task, thereby providing conversational data through recording. Each team shared working with each design process such as a drawing, model or digital file. Cross suggests the "sharing of representations seems fundamental to collaborative design activity" and "team members drawing and re-drawing over shared sketches" (Cross, 2011) p. 24, is to be encouraged. Dong (2005), p. 119, notes that "deriving a representation of the teams shared language" can be useful in framing the design concept. However, it is known that this team learning method does not work as easily in a digital situation because of single command inputs and viewing unless set-up to acknowledge this, but does work well with physical modelling and drawing techniques. It was understood as important to test the group/team working as part of the investigation into appropriate and useful methods.

6.3 Methods: Workshop 1 - Describe Week 1

Reflexive Threshold Concept Questions:

Clarity and Coherency - What lighting terminology do we already know as designers and as building users and can we expand on it through the tasks set?

Coherency and Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for drawing daylight are most successful?

Coherency - What do we understand of "luminance" values when we consider lighting contrast values in multiple ways? What numerical contrast values are significant (what is visible to the eye and how accurate is the eye in determining this)?

Tasks – In Studio Visual Images:

- Describing lit environments -photographic visuals of an architectural space, a personal, verbal, reflexive account
- Re-describing lit environments - photographic visuals of an architectural space in discussion with others, a verbal, reflexive account (adding to own description)
- Creating matching lit environments (2D photographic visual to 2D drawing) through hand drawing
- Measuring contrast of photographic visual and drawing using reflection scale and/or Photolux[2]
- Visual Lexicon - Re-describing lighting terminology through drawings, photographs and numerical data, visual, heuristic and reflexive studies

It was proposed that participants worked on their own representations of a selected set of interior spatial environments to allow a time of self-reflection and individual evaluation of the space. The aim of this part of the study was to engage participants

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[2] Description of Photolux - Photolux for Android is a limited version of Photolux for PC developed by LGCB, a research laboratory, located at ENTPE (Vaulx en Velin, France). http://www.photolux-luminance.com/index.php.

with their own understanding of the ambiance created by the case study example and invite their own translation through written text and drawn image of it through their own representation.

For the second part of the study it was proposed that participants worked in groups to encourage discourse, encourage new vocabularies and “explicit” (Mulligan, 1999) discussion of daylighting language.

6.3.1 Workshop resources – Selected visual images and Case Studies

The images selected for discussion were taken from a selection of daylit spaces serving as case study images. The images were sourced from my own database of photographs, taken from lighting research visits to the buildings (Peter Zumthor, Tadao Ando and Corbusier) and open source images influenced by the photographic examples Plummer presents in his books on architectural daylit spaces.

It is noticeable on reflection that the majority of the selected images are from religious buildings. This is an intriguing discovery as this was not an intentional move. It is apparent that these religious buildings have been designed with care and attention to atmospheric conditions and as such have thoughtfully considered the intervention of daylight into the space. Therefore, although the results demonstrate language used for describing lighting it would be a fascinating further research study to find spaces that are not intentionally designed as spaces with religious atmospheric effect but rather serving other, more mundane functions.

Through the exploration of a given case study, participants were encouraged to explore and challenge the interpretations of other designers’ work. They developed these translations through their own investigations, to identify both conceptual reasoning and the technical integration of concepts into built form, spatial environments, and then through creating their own representations and realisations of daylighting atmosphere.

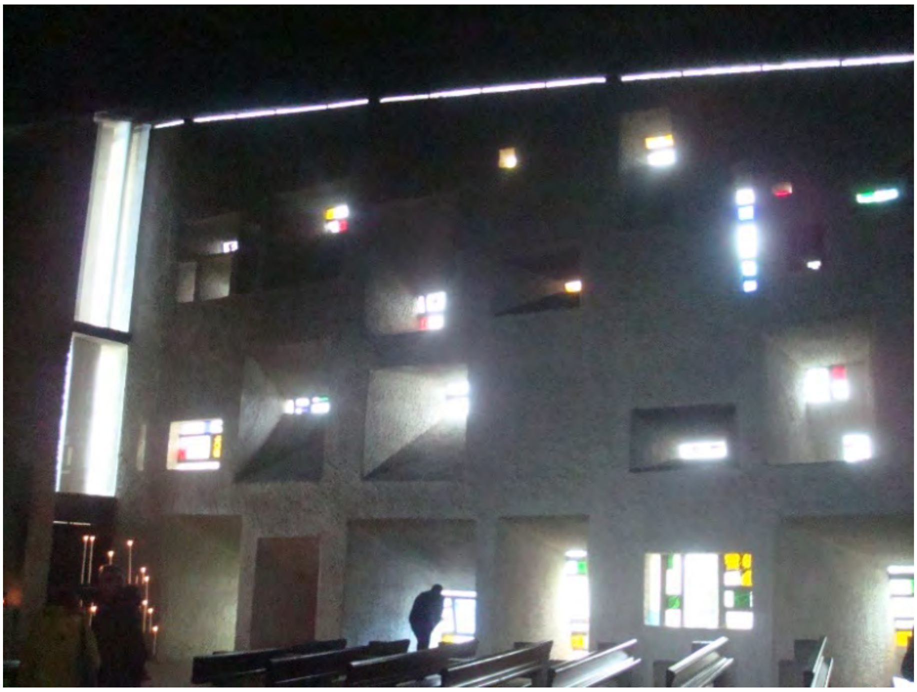

Figure 31 Case Study 1 - Notre-Dame du Haut, France, (Le Corbusier, 1955),

(Source: G.Treacy)

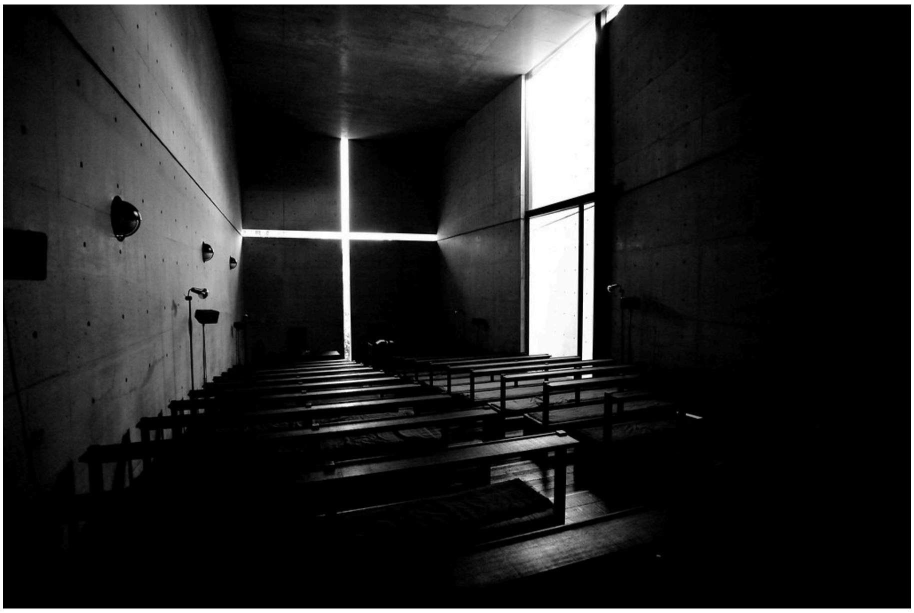

Figure 32 Case Study 2 – Church of Light, Japan (Ando, 1989),

(Source: Creative Commons License)

Figure 33 Case Study 3 – Bruder Klaus Chapel, Germany, (Zumthor, 2007), (Source: Creative Commons License)

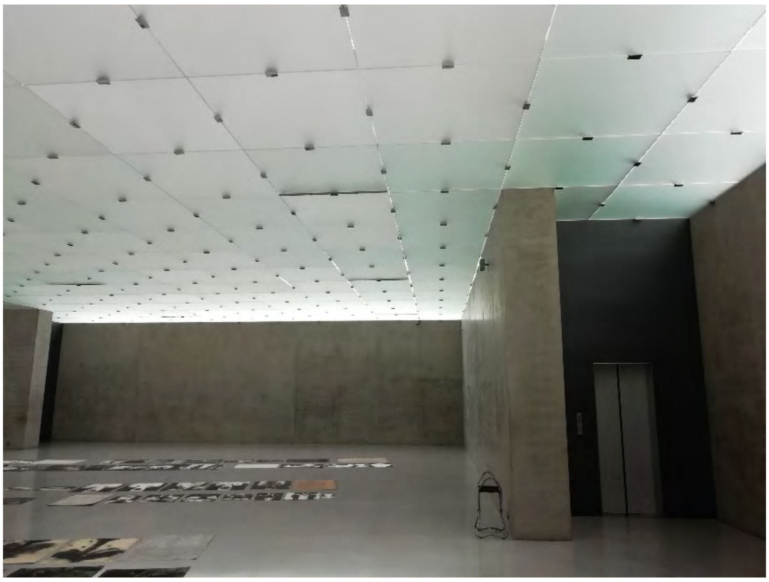

Figure 34 Kunsthaus Bregenz, Austria, (Zumthor, 1997) (Source: G Treacy)

6.4 Methods: Workshop 2 – Field Visit Week 2

Figure 35 Images of participants on site visit to Chaplaincy (note overcast conditions)

Reflexive Threshold Concept Questions:

Clarity and Coherency - What lighting terminology do we already know as designers and as building users and can we expand it?

Coherency and Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for drawing daylight are most successful?

Coherency - Can we understand the numerical outputs for task illuminance as we try to complete physical tasks?

Coherency - What do we understand of “illuminance” values and their relationship to sky illuminance when we consider lighting metrics (DF and “no-sky line”)?

Coherency - What happens to illuminance values as you get closer to or further away from a window and can this be measured to work out a suitable room depth for the given window size?

Coherency and Idiomatic Daylighting Design - If we attempt a hand calculation for DF, why is our answer not equal to the real-time measurement taken?

Tasks – Case Study Building Visit

- Experiencing lit environments – case study building visit
- Describing lit environments through hand drawing and marking numerical daylight values
- Measuring lit environments -photometric absolute value measurements of building and DF hand calculation, a heuristic, reflexive account + DF with Edenapp
- Experiencing lit environments through physical measurement of "no-sky line" and DF, a heuristic, reflexive account
- Visual Lexicon - Re-describing lighting terminology through drawings, photographs and numerical data, visual, heuristic and reflexive studies.

6.5 Methods: Workshop 3 – Create model: studio Week 3

Reflexive Threshold Concept Questions:

Clarity and Coherency - What lighting terminology do we already know as designers and as building users and can we expand on it through the tasks set?

Coherency and Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for drawing daylight are most successful?

Coherency - What do we understand of "luminance" values when we consider lighting contrast values in multiple ways? What numerical contrast values are significant (what is visible to the eye and how accurate is the eye in determining this)?

Clarity, Coherency, Idiomatic Daylighting Design and Orchestration - What lighting terminology do we already know as designers and as building users and can we expand it as we describe a 3D physical spatial model with group members?

Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for modelling daylight and sunpath are most successful?

Tasks – In Studio Building Physical Scale Models

- Creating matching lit environments (2D visual to 3D model) through physical modelling of a participant's selected case study hand drawing – swap with adjacent group with different case study (This workshop method was to highlight the range of translations possible and expose different ways of understanding the same space as individual designers - discovery of lost in translation. Photographic visuals were presented after 10mins with group discussion to highlight and clarify any translational issues)
- Describing lit environments through physical, scaled modelling, a heuristic, reflexive study
- Re-describing lit environments - visuals of an architectural space in discussion with others to translate into a physical model, a verbal, reflexive account to 'match' a given atmosphere
- Measuring lit environments through exploring solar path (measuring angles) and location/context of case study building, verbal, heuristic, reflexive study
- Visual Lexicon - Re-describing lighting terminology through drawings, photographs and numerical data, visual, heuristic and reflexive studies.

6.6 Methods: Workshop 4 – Model: VE Week 4 or 5

(Group split into two, swapping Workshop 4 or 5 each week, Group C as 5 consecutive groups one following the other over one afternoon)

Reflexive Threshold Concept Questions:

Clarity and Coherency - What lighting terminology do we already know as designers and as building users and can we expand on it through the tasks set?

Coherency and Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for drawing daylight are most successful?

Coherency - What do we understand of "luminance" values when we consider lighting contrast values in multiple ways? What numerical contrast values are significant (what is visible to the eye and how accurate is the eye in determining this)?

Clarity and Coherency - What lighting terminology do we already know as designers and as building users?

Coherency - Do we have enough lighting vocabulary to use lighting simulation VE software? (e.g. do we know what input values to use and are the resulting numerical values as expected)?

Coherency - Can we experience the changing numerical outputs for task illuminance as we manipulate the 3D model or alter the input values? What factors of the spatial design change the illuminance values?

Coherency - What do we understand of "illuminance" values and their relationship to sky illuminance when we consider lighting metrics (DF and "no-sky line")?

Coherency - What happens to illuminance values as you get closer to or further away from a window and can this be measured to work out a suitable room depth for the given window size?

Coherency and Idiomatic Daylighting Design - If we attempted a hand calculation for DF on the site visit, why is the answer not equal to the VE result?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for modelling daylight are most successful?

Tasks – In Computer Lab Manipulating IES VE Models

- Measurement of Illuminance and DF using software and 3D VE model, a heuristic, reflexive study with others
- Re-describing and manipulating, 3D VE models to comply with given daylighting metric values
- 'Post it' (brief focus group session)

As per the Pilot Study Workshops a 3D model was prepared in SketchUp and a set of workshop notes created to provide additional guidance during the Workshop and for participants' future reference. However, for this workshop, participants were provided with the 3D virtual model of the case study, the *Edinburgh University Catholic Chaplaincy Chapel,* to use for the tasks within IES VE[3] software. After a 15 minute demonstration tutorial, each small group followed through calculating the daylit environment using basic sunlight and daylight metrics referring to a set of worksheets available as digital documents if required.

Additionally, participants were then asked to manipulate the model to provide a reduced and/or increased Average Daylight Factor result. Using the tools available in the software, participants changed the values of the various design parameters available to them to evaluate the results in relation to the element manipulated in the VE model.

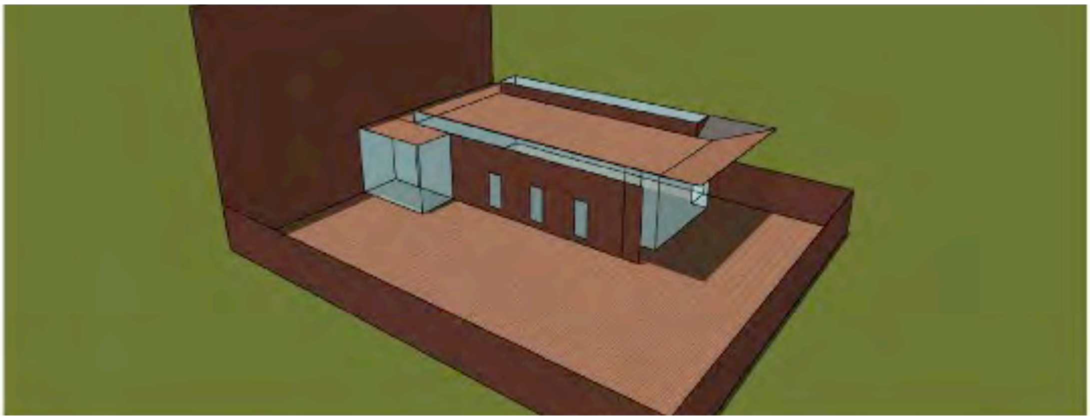

Figure 36 Sketchup model of the University of Edinburgh Chaplaincy Chapel imported into IES VE Suncast.

[3] IES VE - https://www.iesve.com/

6.7 Methods: Workshop 5 – Model: studio Week 4 or 5

(Group split into two, swapping Workshop 4 or 5 each week)

Reflexive Threshold Concept Questions:

Clarity and Coherency - What lighting terminology do we already know as designers and as building users and can we expand on it through the tasks set?

Coherency and Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for drawing daylight are most successful?

Coherency - What do we understand of “luminance” values when we consider lighting contrast values in multiple ways? What numerical contrast values are significant (what is visible to the eye and how accurate is the eye in determining this)?

Clarity and Coherency - What lighting terminology do we already know as designers and as building users?

Coherency - Can we experience the changing numerical outputs for task illuminance as we manipulate the 3D model? What factors of the spatial design change the illuminance values?

Coherency - What do we understand of “illuminance” values and their relationship to sky illuminance when we consider lighting metrics (DF and “no-sky line”)?

Coherency - What happens to illuminance values as you get closer to or further away from a window and can this be measured to work out a suitable room depth for the given window size?

Coherency and Idiomatic Daylighting Design - If we attempted a hand calculation for DF, why is the answer not equal to the physical model result?

Clarity, Coherency and Orchestration - As a spatial designer, what techniques for modelling daylight are most successful?

Tasks – In Studio Manipulating Physical Models

- Using Case Study buildings 1,2,3 or 4 as given - manipulating physical models to comply with metric measurements
- Measuring lit environments - photometric absolute value measurements of Illuminance, luminance (contrast) and DF using physical model, a heuristic, reflexive account Measuring contrast of photographic visual of the physical scale model and/or drawing using reflection scale and/or Photolux[4]
- Manipulation of model to change the Daylight Factor (increase or reduce)
- Re-describing lit environments through drawing and photographing physical models, visual and heuristic study
- Visual Lexicon - Re-describing lighting terminology through drawings, photographs and numerical data, visual, heuristic and reflexive studies
- 'Post-it' feedback

6.8 Methods: Workshop 6 - Visual lexicon Week 6

Reflexive Threshold Concept Questions:

Clarity, Coherency and Orchestration - What lighting terminology do we know as designers and can we individually create visual representations of this?

Coherency and Idiomatic Daylighting Design - Do we all experience and describe the lighting atmosphere of a space in the same way?

Clarity and Coherency - What do we understand of "luminance" values when we consider lighting contrast values in multiple ways? What numerical contrast values are significant (what is visible to the eye and how can we present this in 2D or 3D)?

[4] Description of Photolux - Photolux for Android is a limited version of Photolux for PC developed by LGCB, a research laboratory, located at ENTPE (Vaulx en Velin, France). http://www.photolux-luminance.com/index.php.

Clarity, Coherency, Idiomatic Daylighting Design and Orchestration - As a spatial designer, what techniques for drawing, modelling or representing daylight are most successful?

Tasks – In Studio Reflexive Lexicon Completion

- Re-describing lighting terminology through drawings, photographs and numerical data, visual, heuristic and reflexive studies.

Participants were asked to describe a (day)lighting term and present this visually in a (day)lighting lexicon. This lexicon served as a sketchbook to record any such actions, design ideas and/or methods to achieve atmospheric spatial effects with daylight that could align with descriptive text on a weekly basis. Although it was assumed that participants would create pages within their lexicons presenting daylighting terminology or metrics covered in the workshops in a visual way, the lexicon was not restricted solely to this topic. It was agreed in the first workshop with participants that general lighting concepts, atmospheric descriptors, or numeric data also were acceptable for inclusion. This was agreed to ensure the creation of a lexicon was as valuable a record as possible for each participant.

6.9 Workshops 7 + 8 – Focus Groups

Focus group meetings + Reflections

Group selection of time slot and date, submission of sketchbook and/or models and visual lexicon. Workshop participants agreed to bring their lexicons for discussion at the focus group session in week 7 or 8 if they wished to participate.

6.10 Findings of Observations in Workshops

6.10.1 Researcher's Recording of Workshops

The analysis of explicit knowledge presented by participants was considered as valuable data for this research project. This data was crucial in the search to understand and evaluate the workshop tasks, processes, and their subsequent influence and success in the learning and realisation of daylighting concepts contained within the work in progress and completed group work.

In this studio context, group discussions were recorded through sound recordings and activity action to ensure any explicit presentation of principles by individuals was acknowledged; those individuals showing full awareness and consciousness of these principles within group discussion.

6.10.2 Visual analysis

This analysis technique was critical for these workshops as participants' conversations alone did not provide a full understanding of the scenario and the objects the participants were discussing within the workshops.

Although participants had been asked to record their model making work as photographs during the workshop set, unfortunately very little evidence of this was brought to the focus groups for discussion. At the end of each weekly workshop, general discussions had highlighted the various concepts found and clarified these where possible.

Visual analysis was carried out through observation during the workshops. During the first workshop participants chose to draw their case study building using various techniques. However, when possible, in addition, participants used Photolux to determine luminance values to find relational values to the media they had used (hand drawings or physical models). As this technique had been discovered in the pilot studies, it was now possible to integrate this simultaneous viewing of the drawing and relational luminance values into the workshop tasks. Scales were created to match the drawing technique used and one group chose to work in reverse using this scale. Once they had their scale worked out they changed the luminance values in the space then tried to generate the drawing to suit. This result was recorded and discussed. Participants commented that they had changed their position in the studio space for the second drawing and the light was therefore landing on the drawing from a different direction. Another participant commented that the light was changing "because of the sky" so that was also why it was difficult to make the values (absolute) the same.

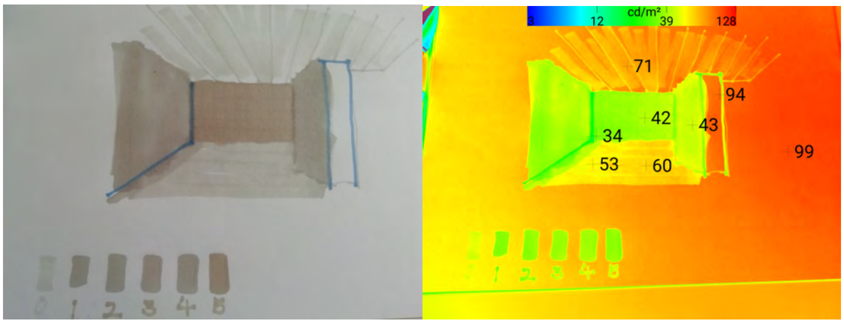

Figure 37 Case Study 3 - Finding values using Photolux

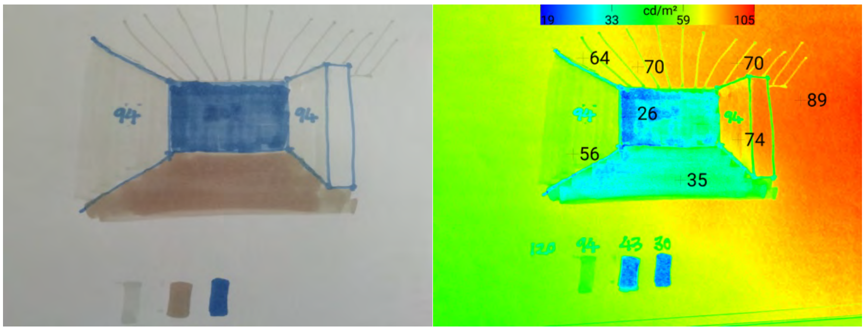

Figure 38 Estimating marker pen values, then testing with Photolux

Drawings of the final models were limited as participants has little time to do this final task within workshop time. As these workshops were non-assessed it was found that participants produced very little drawing or modelling work out with the workshop time slot. Where it was of particular interest, and practical, the actions of group members creating and adapting the physical models were noted to accompany the transcripts.

6.10.3 Workshop 1 - ‘see’ing - Results

Student participants were able to describe the photographic visuals well in Workshop 1 with significant evidence of individual use of descriptive language for the lit scenarios. As part of the task, participants were then asked to re-group and discuss their individually assigned case study photograph with others to expand on their text. This method worked successfully, to first determine new language, second, to note where new language was added due to the group interactions, and how the descriptive language can evolve working as individuals collectively discussing the same space. See sample sheets with new language acquisition noted in a different text colour/below the line (additional sheets are available to view in Appendix VI).

Figure 39 Case study 1 Participant drawing and space description

6.10.4 Workshops 3+4 - ‘touch’ing – Physical Model Results

In Workshop 4 participants worked quickly and confidently to develop spatial voids which they filled with texture, colour and light. Some participants used transient sunlight to explore ephemeral atmospheres. Others used static artificial light and layered the spatial armature with paper and shading charcoal to change the tones (reflectance values) and textures to correspond with their understanding of the space. Most models created had no determined scale but were successful nonetheless in realisation as it quickly became apparent to the participants that light has no scale anyway so they could push this boundary as they wished. Many models had a clear observation angle. Conversation analysis during group work made this phenomenon explicit as participants discussed the viewing angles, location of the sun and the orientation and height of their models.

In the second part of the workshop students sought to measure the lit ambiance of the physical model photometrically. Participants used Edenapp and Photolux to calculate illuminance levels, luminance and DF values. Participants were then asked to adjust these measurements to suit a given lighting metric requirement through manipulation of the model. It became apparent very quickly that this was possible and connections were strong linking the metrics with the physical model materiality, opening sizes etc. Each causal architectural relationship within the architectural space needed consideration and this was easily tested using physical materiality and mobile phone light sources. Again, the accuracy of the absolute values measured here were less critical but the threshold concept of, relationally, what physical model adaptions provided changes in these numerical output values was emphasised It was however suggested that participants should use the same device for measuring throughout the workshop session to keep the results as continuous as possible (if not under primarily daylit conditions), and this undoubtedly helped with this task.

6.10.5 Workshop 5 - ‘touch’ing – VE model results

In the Model:VE Workshop participants found it quick and straightforward to create photometric data for their 3D virtual environment model of the University of Edinburgh Catholic Chaplaincy (St Albert The Great). However, the output data as Isolux diagrams, numeric DF values and contrast ratios could only be explained by a few participants however. This lack of understanding of these numbers and the relational values to the interior space and external context was further demonstrated in the subsequent workshop.

The following week, when participants were asked to adjust their VE model to suit the metrics given for compliance, the following situation arose. Initially participants were unclear as to which input variable to select but very quickly using a trial and error approach, allowing multiple scenarios to be evaluated, showed in the production of numerical results that were either higher or lower. Significantly, it was noted by most participants that the reflectance of ceiling material selected became crucial to the metric values achieved. When participants were asked to discuss how this change in reflectance might be created in a real project, with real materials, most assumed the use of mirrored surfaces rather than changing the colour (absorption of the material). It became clear that the participants were making changes to their design without really reflecting or understanding the nature of their revisions, and the impact on the architectural aesthetic, or change to spatial perception in achieving the required results.

Nicholas Carr, in writing an article about on-line learning, discusses controversially that in using digital software we are frequently just ‘decoders’ (Carr & Norvig, 2010), considering unrelated parts of information out with known contexts. The findings of this study imply that this may be happening when we use digital software for daylighting without a basic knowledge of the processes involved. A lack of haptic engagement presents itself through observing this virtual scenario, created using digital lighting software devoid of experiential context. Pallasmaa (Teal, 2010) proposes that, “touch is the unconsciousness of vision, and this hidden tactile experience determines the sensuous qualities of the perceived object”. Without this physical appreciation of the behaviour of daylight interacting with the materials this appears to be problematic.

Some surprising findings related to IES VE with Group A participants in comparison to Group B participants. Feedback from the participants in Group A confirmed that these participants were inspired and challenged in different ways by the IES VE software Workshop. Their feedback noted how useful IES was to perform calculations that they would otherwise not have known how to do. Intriguingly it was this feedback and only at this point in the research study that a difference between the groups defined as “spatial designers” became clearly apparent.

With Group A, composed as a group of interior design participants, this ontological view of daylight coincided with an understanding of their CoP and, as such, likely defined the boundaries of their scope of interior analysis and tools. However, not only had they found a new method of engagement with design scenarios that might often have been viewed as for architects only. However, as the interior design participants were already equipped with excellent computer drawing experience and Sketchup skills they were able to engage in a more successful way than Group A, the architect participants. With Group A, using Sketchup provided them with a simple method to input their own information into the program and analyse their buildings, relying less on their own mathematical skills and more on their CAD methods.

Group B, year 2 Architecture students had not been exposed to a similar amount of training in 3 dimensional model building using computer technology prior to their experience of IES. This highlighted a key factor in the successful implementation of the technology; familiarity of methodology - whether the student had previous experience and confidence in 3-dimensional computer drawing.

6.11 The use of Linkography for workshop analysis

The research workshops had been recorded through following selected group conversations (verbal sound recordings and the researcher's notes of actions) as the tasks were undertaken and collecting examples of the outputs as photographed by the participants. Additionally, the focus groups (weeks 7 and 8) were recorded using sound recordings as the reflexive threshold concept questions were discussed. Both types of events were considered important for the collection and analysis of data as data collected in the studio, lab or building visit was direct and unedited until coded by the researcher. Data collected from the Focus Groups with the workshop participants was particularly relevant. It provided explicit opinions and feedback even although this feedback was understood to be influenced by participants' expectations of what the Focus Group questions required of them and a manipulation of thinking to ensure a correct answer for the Focus Group Facilitator.

The pilot study workshops had been analysed to reveal emerging priorities and themes using NVivo software. Although NVivo had clarified groups of design language used to describe lighting generally and had provided some indication of learning from review of focus group verbal discussions it was difficult and cumbersome to analyse design moves or protocol analysis with any depth as no connections between ideas could be seen visually. Each section of parsed conversation required categorisation and then further manual definition of any patterns or connections to provide useful data for analysis and sit within the methodology proposed. However, as it had been found through observing the pilot studies that participants' conversations and actions whilst undertaking the tasks, pointed towards findings that indicated an individual participant's ontological approach (individuals within groups), it was proposed that it was worth pursuing investigation of alternative methods.

Further investigations into protocol analysis revealed Linkoder[5], a research analysis tool based on the creation of Linkographs (Goldschmidt, 2014). In the majority of published work on this method Linkographs are often used to find important moments in design decision making and associated moves that lead to the final idea or concept (Goldschmidt, 2014) (Al-Sayed, Dalton, & Hölscher, 2010) (Cai, Do, & Zimring, 2010). This analysis software uses parsed conversations to characterise patterns in design protocols. After a sample study of the first conversations recorded in this research study (Workshop 1 week 1) using Linkography and through a review of literature demonstrating the use of Linkography in other research projects, it was proposed to use this tool for all conversation and action analysis of workshop results. The type of data collected in the workshops was suitable for Linkography analysis. The requirements of the coding system possible to define and the output Linkographs provided new findings, based on ontological perspectives to emerge.

Using Linkoder conversations and/or actions are parsed into design protocols and turned into coded segments. The software then produces a Linkograph, a graphical web of conceptually connected segments of the event or series of events using these coded design protocols, through coding built into the software. Coding of the data requires an alignment both ontologically and epistemologically with the FBS framework around which it is based: The FBS (Function Behaviour Structure) design ontology and FBS protocol coding scheme. This framework is known to be a principled ontological method that is understood to be universal and “applicable to design protocols independent of their domains and subjects” (Goldschmidt, 2014) with LINKODER as a standardised tool which is usable in different research scenarios.

In order to capture the dynamic nature of designing, LINKODER treats the coded protocols using three additional approaches: fractioning, windowing and trimming. Applying these treatments to different standard analyses generates insightful results about the “dynamism of designers’ behaviours during the design sessions” (Goldschmidt, 2014). However, as the data generated by the design tasks was not particularly long (brief 3min sessions of talk were analysed) due to the nature of the tasks there was a lot of “making”, rather than a constant flow of discussion. This analysis method, although clearly limited in its value due to the short sections of conversation could still be used to determine how useful certain design protocols were

[5] https://sites.google.com/a/linkoder.com/linkoder/home

(in action and language used) towards the understanding of and connection with new concepts, consolidating known concepts or inspiring new concepts.

The next section of the thesis outlines the ontology defined by the situated – function-behaviour-structure framework and relates this to its new purpose in this study, for the domain of daylighting, used for pedagogical insights.

6.11.1 The Situated Function-Behaviour-Structure Framework

The situated FBS framework was developed by John S. Gero and Udo Kannengiesser (2004) as an extension of the FBS (Function, Behaviour, Structure) framework to explicitly capture the role of situated cognition or "situatedness" in designing.

When reviewing findings from the Pilot Study Workshops it was evident that the lack of "situatedness" of the case studies was problematic. Constructivists such as Brown et al (Brown, Collins, & Duguid, 1989) emphasise "situating" cognitive experiences. Without "situated" learning, "decontexualisation" results in a lack of transfer between the two environments such as the learning environment and the real environment. Therefore, if using Constructivist methodologies, it was imperative to "focus on developing the skills of the learner to construct and reconstruct plans in response to situational demands and opportunities" p. 4.

The basic Constructivist assumption underpinning the situated FBS framework is that designing involves interactions between three worlds: the external world, the interpreted world and the expected world. The key theoretical approaches underpinning of Gero and Kannengisser's Situated FBS methodological approach were re-defined and "situated" for this daylighting research study as follows:

External world	Contains things in the “outside” world (for example, in the physical, built environment of the spatial designer through haptic engagement with solar trajectory)
Interpreted world	Contains experiences, percepts, concepts and epistemologies, formed by the spatial designer’s interactions with this external world
Expected world	Contains expectations of the results of the designer’s actions, driven by goals and hypotheses about current understanding of the world (influenced by cultural background, education, Community of Practice and other influences)

Fig 40 Adaptation of Gero's Ontological Steps

Gero proposes that the three worlds are interconnected by classes of interaction.

The FBS view of objects

The FBS ontology provides three high-level categories for the properties of an object:

1. The function of an object is defined as its teleology (“what the object is for”), which is largely domain dependent.

2. The behavior of an object is defined as the attributes that can be derived from its structure (“what the object does”). Most instances of behavior are domain dependent.

3. The structure of an object is defined as its components and their relationships (“what the object consists of”). The structure of most objects can be described in terms of geometry, topology, and material.

(Gero & Kannengiesser, 2004), p. 380.

On first observation it is apparent that Gero’s framework aligns with objects, product design and assembly. However, if we consider the design object within this research study as the lit architectural space, we can begin to propose the FBS framework as a viable option for analysis.

These categories present as having direct consequence to workshop findings within this research study and align closely with the Daylighting Design Competencies as task objectives proposed for this study. They are therefore proposed below to define their place within the domain of daylighting:

- **Clarity in Daylighting** *(preciseness in daylighting terminology, appropriateness of daylighting method for evaluation process or output, clarity in representation of daylight)*
- **Coherency of Daylighting Concepts** *(relational daylighting concepts between qualitative and quantitative, relational representations of visual to numeric/numeric to visual)*
- **Idiomatic Daylighting Design** *(appreciation of personal response and atmospheric phenomenological characteristics of daylight, solar path, climatic variations specific to context/location)*
- **Orchestration of Daylight** *(synthesis between all spatial elements, qualitative and quantitative).*

Gero's Framework	Research study Approach
Interpretation	Transforms variables sensed in the external world into variables within the interpreted world **(Coherency of Daylighting Concepts - relational)** **Coding used for Linkograph:** **FUNCTION relating to STRUCTURE (Fs)** **FUNCTION relating to expected behaviour (Fe)**
Focussing	Selects subsets of variables in the interpreted world and uses them as goals in the expected world **(Clarity in Daylighting and method)** **Coding used for Linkograph:** **FUNCTION (Fe)**
Action	Changes the external world according to the goals and hypotheses composing the expected world **(Idiomatic Daylighting – understanding of unique characteristics and nuances)** **Coding used for Linkograph:** **BEHAVIOUR relating to STRUCTURE (Bs) or** **BEHAVIOUR relating to expected behaviour (Be)**

Constructive memory	Produces memories as a result of re-interpreting past experiences. It is based on a constructivist model of human memory in which new memories are generated by reflection and understood in relation to the whole context. (The paradigm within which a designer creates and constructs knowledge of the domain) **(Orchestration of Daylight)** **Coding used for Linkograph:** **STRUCTURE (S)**

Figure 41 Interpretation of Gero's 'Situated FBS Framework' for a daylighting workshop context.

The Situated FBS coding strategy approach allowed each recorded conversation relating to design protocols to be analysed and connected/associated to the appropriate Daylighting Design Competancy; F, B or S. This coding, as interpreted above, was assigned to each parsed utterance in the recorded Workshop conversations to suit its over-riding theme of Function, Behaviour or Structure. In some research situations this coding is created and analysed in parallel to ensure parity in translation and approach to results. This approach obviously provides more consistency in translation. However, for the research study it was not possible for two people to carry out the analysis and it was therefore accepted that the interpretation of each phrase proposed by myself would suffice as a first attempt. The participants attending the focus groups were asked to consider some examples of the conversation and its associated coding, proposed by myself, to assess the accuracy of the interpretations I had made.

6.11.2 Insights from Linkography Analysis

Using the the Situated FBS coding strategy each set of conversations was parsed, numbered and coded into an Excel document and fed into Linkoder to create its associated Linkograph. The Linkographs created for each conversation began to suggest new findings in relation to ontological moves, supporting findings relating not only to revealing ontological perspectives but some shifts in epistemic perspectives too.

On the Linkograph each link relates to a design action or action bundle which collectively demonstrates movement in thinking and process. Each action is connected through a 'back-link' or 'fore-link' connector and informs of a new consideration or thought. From this data we can see that changes in thinking through words or action frequently happen in groupings. Within the conversation bundle some actions or words provide more or less links in either direction, identifying stringer or weaker connections to the idea at that time.

Through the coding and development of this method of analysis for this research, it became clear that the Linkograph was exposing more than simple Threshold Concept connections. In conversations from the Create Model: Studio Workshop (see Appendix), we understand that changes in design language are significant, not simply because of the length of the exchange but also the acceptance and reflexive discussion of specific vocabulary from one participant to another. In the other conversations recorded as part of this workshop was less apparent as individuals chose not to agree in the discussions or take onboard other group members comments. Few connections were shown on the Linkograph with an occasional connection made towards the end of the workshop conversation recording. As coding progressed each move was evaluated and coded using the FBS framework further, stronger links were apparent relating to larger, overarching focussed engagement with 'threshold concepts' within the duration of the conversation. For this specific analysis study these sets of links (understood as connections) varied in frequency, length between connections and density in some areas. These results are therefore clearly dependent on the discussions and actions undertaken and, on a closer level, the medium used and the process being carried out.

Additionally, as the corresponding actions to the parsed conversations (as noted by the researcher) were analysed, the groupings of nodes are seen to be shorter when the challenges are less great and results from the Create Model: Studio Linkographs show this pattern compared with Model: Studio (see Appendix VI). For example, the physical action of measuring and then defining the lighting contrast through drawing not only allows different applications but invites confidence as the scale is still personal yet relatively uncomplex. Further, it is proposed that when the challenges are of medium difficulty for the participant we can see full engagement with many linked connections during a short period of time. This was shown in Linkographs Model: Studio (see Appendix VI). These conversations were taken from both Model:

Studio Workshop, where participants had been asked to develop physical, alternative, design interventions to change the numerical daylighting value. However, conversations from Create Model: Studio when working with IES VE and tackling a similar set challenge showed very differing results. Moves with few forelinks or backlinks were identified. Although difficult to define with such a small sample set of results I propose that these results suggest less-connected learning and evolution of design ideas.

However, what is most significant is the learning that seems to appear at the connecting points of these groupings. An idea or Threshold Concept becomes apparent as we examine clusters within the Linkographs. We can therefore identify that the most active learning mentally can be seen when we jump between these modes of action groupings..

Critical to this analysis, the tangents (larger leaps indicated by the longer lengths between intersected phrases), produced during these areas of activity often provided a single backlink to a previous idea. Most often this was found to occur individually, with other group members not responding in the same way. These results provided insights about learning that could relate directly to engagement and debate around a theme linking back to a much earlier design notion for some and for others no backlinks occurred. It is proposed that these moves within the Linkograph that could be defined as epistemic.

The movements coded displayed new associations and leaps in understanding (Lawson, 2006) or epistemic moments in the process of the workshop activity. The realisation that this ethnographic methodology of verbal/action of participants taking part in a daylighting design task could provide a useful source of data was significant. The verbal/actions of participants, recorded in workshops and the subsequent conversational/action image analysis could highlight moves where a change in thinking happened, was crucial to the development of findings from the workshops. Most importantly, within this educational research context and further to focus group discussions with participants, it is proposed that these epistemic moments in many cases revealed a change in the understanding of a concept(s). ”Experience has to be arrested, examined, analysed, considered and negated to shift it to knowledge” (Costas Criticos Ch 11 in (Boud, Cohen, Walker, & Society for Research into Higher, 1993). This “shift in knowledge” is therefore formed through development of experiences within the workshops.

It is proposed that the moves identified in the linkograph did not simply provide information on the move with the most connections, but provided a change in direction of the linkograph with the action/verbal descriptor or word becoming valuable in ascertaining epistemic experiences/events. As the workshops were carried out further testing of coded connections were identified and built upon. The linkographs began to highlight the actions and working methods that produced the most successful links epistemic moments. These moments could also be associated with visual links as well as moments found through conversation analysis. For example, this was seen to occur when participants used the Photolux app with some success to analyse their drawn or physical representation. The connected discussions when considering the space and its associated luminance levels provided clarity for some participants and encouraged further investigations in some groups to test this and adapt the model or drawing to suit their desired atmosphere.

It is understood that most flashes of creativity—the ‘eureka’ moments—will occur long after relevant knowledge is acquired (Johnson, 2010). However, it is clear that without some basic understanding of daylighting such traces of creativity would never occur as the relevant technical knowledge to realise the evolved idea would not be to hand. The notion of the traceability of these epistemic moments was considered an intriguing line of analysis to pursue to provide a measure of any successful workshop methods employed and the nature of what these epistemic moments might be in this specific context.

6.11.3 Focus Group Discussions of FBS Coding

Each workshop was discussed in the subsequent focus group sessions and a key element of daylighting knowledge and design epistemology emerged. The exploration of these relationships *between* light and architectural space served to help visualise this embodiment explicitly. It was necessary for these design explorations to be interactive and encourage iterative variables in order to unravel the varying relationships between materials, light and photometric values.

Some of these activity methods tested in the workshops were shown to be more or less effective in producing epistemic experiences and these were discussed with the participants in the focus groups. It was necessary for the validity of the research to seek information from participants to check alignment of the analysis results and test the experiential value that the participants attributed to these highlighted events.

As participants were introduced to the coding, three examples of each type were provided. Participants were asked to discuss a single conversation in three small groups that had been parsed and coded using FBS. The results for the re-coding of the conversations can be seen below with areas of disagreement in red. It was fascinating to see that the majority of moves within the longer conversation were coded and analysed in a similar way. One group found more discrepancies and had allocated more segments of conversation to structure (S) as they had understood that many notions of daylight “had a lot more going on than just one thing at a time”. In order to reduce the complexity of this process the further underlying focus of each code F,B or S in relations to “structure” or “expected behaviour” was not included within the focus group discussions.

One area for further discussion was highlighted by a participant group where a participant used an alternative method/approach within the conversation to positive effect. It was interesting to note that the participants themselves had found this insight during their own reflections of their behaviour in the same exercise and had understood that an alternative approach had been a successful one for others.

6.12 Summary of Insights

The Workshop set sought to identify key aspects of learning in relation to the usefulness and success of the methods tried and their perceived value to the participants. Each workshop method was therefore identified as appropriate for the participants group with the use of physical modelling and drawn methods most beneficial to “exploring” and learning to ‘see’ and ‘touch’ light.

However, caution is encouraged with all forms of exploration whether physical or virtual as it is necessary to reflect on and check the concepts in each scenario have been understood. It is too easy to “play” with a mobile phone light to create interesting effects that are neither physically representative of daylight or quantitatively correct unless informed and considered relationally. Further, in virtual environments it was very straightforward to “calculate” the lighting quantitatively without understanding the default values used by the software, or even understand the random input values the participants used.

The epistemic nature of design moves, even with “novice” designers became a tangible reality using recorded conversations and actions analysed using Linkography. Although Linkography had not been applied in this way before, the results it generated using standard procedures were new and challenging for the field of daylighting design.

Chapter 7 Discussion

7.1 Introduction to discussion of findings

This research study was based on an ethnomethodological approach which provided opportunities to first investigate contextual issues through pilot study questionnaires (design students and practitioners) and literature reviews, and then to explore these insights through workshops with participant feedback. Through qualitative and quantitative analysis of these studies, common themes emerged. These themes are noted in Chapter 3 and outlined again below to clarify their relationship to the findings from the resulting research workshops (pilot study set and main research study set):

- **The current role of daylighting and the value it is assigned by spatial designers through their engagement with it within the architectural design process**
- **The ontological perspectives of educators in relation to daylighting and how this affects the separation between qualitative and quantitative ontologies**
- **The difficulties of working with lighting terminology (the words and the numbers) and the need for translation into spatial design language**

With these themes highlighted by the pilot study questionnaires and literature, textbook and journal reviews, it was then possible to question and challenge these themes through exploration of initial pilot study workshops and subsequently the main research project workshops. Whilst analysing and writing about each of these workshops and their associated Focus Group sessions, further insights emerged. It was at this point in the research study that a proposed and subsequently defined methodology began to become clear. This redefined approach pointed towards the need for an integrated *methodology* for design students, rather than a specific method or tool to contribute to daylighting pedagogy. This developed methodology for daylighting would allow for current and future demands and technologies to be embraced, rather than identify and align with a specific tool that would risk being outdated prematurely.

The themes that emerged from the main research workshops and Focus Groups, included in this discussion chapter, were determined through exploring practical applications of design teaching methods and tools. The analysis of workshop conversations and participant outputs demonstrated specific examples of behaviour that revealed fragments of participants' learning, positioned within these larger themes:

1. **The use of Linkographs to define moments of learning or 'epistemic' significance in design protocol studies**
2. **The use of a dual-ontological approach with threshold concepts, through workshop content and methods in real or virtual "situated" environments**
3. **The use of daylighting heuristics and their success in engagement with the unfamiliar through relational approaches**
4. **The use of reflexive lexicons in building design language**

This chapter of the thesis therefore discusses findings from the pilot study workshops as described in Chapter 5 and the main research workshops in Chapter 6 under these themes. Although not arranged as a list of headings in order of priority, it was considered important to sequentially link the themes as they had been revealed in the study. Additionally, for the purposes of clarity, these themes are defined as research questions. The final sections of this discussion chapter serve to highlight and summarise the themes and connections that emerged between the two phases of the pilot studies and main study.

7.2 How can we use Linkographs to reveal moments of learning or 'epistemic' significance in design protocol studies and what significance can this have for design pedagogy?

For this research study, a variation of a standard method of Linkography protocol analysis was used. This methodology allowed for analysis of workshop recordings, photographic stills and sound recordings of the participants as they progressed through the workshop activities. Linkography, using Function-Behaviour-Structure (FBS) ontology (See Chapter 4), is commonly used in design protocol studies to find and define connected design ideas (Al-Sayed, Dalton, & Hölscher, 2010), (Cai, Do, & Zimring, 2010) and (Goldschmidt, 2014). The FBS coding system was used for this study as an underlying generic descriptive model of each design protocol, assigned by myself as the researcher, to each segment of recorded conversation (a single line or phrase). The use of the FBS system is described further in Chapter 4 in relation to this particular research project.

The visual Linkograph, generated from coding of the content of parsed design conversations into “design moves”, tracked the generation of a design idea and its progress through “links” (Goldschmidt, 2014) pp. 47-52.. This was demonstrated through reviewing the links in the evolving parsed conversation linking back to a previous idea, “back-link” or forward progression of an idea as a “fore-link” (Goldschmidt, 2014), p55. Where the links intersect, a node is created graphically, informing of a connection between strands of the design conversation called “Critical Moves” (CM), (Goldschmidt, 2014).

However, in this specific case, when applied to a new paradigm for this research study, ‘the generation of and connections between threshold concepts in daylighting workshops’, the links within the Linkograph were used to serve a new purpose. Through the coding and development of this method of analysis for this research, it became clear that the Linkograph was exposing more than the expected design concept connections, or CMs. As coding began and each design move was evaluated and linked to each other, recorded as an action and/or verbal discussion, it became possible to see moves within the Linkograph that could be defined as important in demonstrating learning.

The realisation that this ethnographic methodology of verbal/action of participants could further my findings was crucial to the development of my research. It was possible for participants to take part in a daylighting design task, recorded in workshops and the subsequent conversational/action image analysis could highlight when and where a change in thinking happened. The design protocols coded using this method, displayed new associations and leaps in understanding (Lawson, 2006) or ‘epistemic moments’ in the process of the workshop activity. Within this educational research context, it was significant to find moments in a participants’ design process that revealed a change in the understanding of a daylighting threshold concept(s). It was considered valuable to analyse scenarios to find when and how connections to threshold concepts occurred within the workshops. It is proposed that learning occurred when a series of linked phrases that were coded as ‘structure’ linked back and forward to other design moves, particularly through a large combination of links. This type of relationship was important in defining instances of new learning.

I propose an ‘epistemic moment’, is a situation in which a learning event emerges – often quite suddenly. This ‘epistemic moment’ could be recognised as a leap in learning and understanding, akin to Cross’s “perceptive insight” that characterises creative design activity as a leap in creative thought as appropriate connections occur. Analysis carried out using Linkographs for the research workshops (as set-out in chapter 6) proposed that for some participants, specific workshop tasks and the heuristic actions associated with them, incited ‘epistemic moments’ to occur. The investigations discussed here are based on examples of workshop scenarios within which it is proposed that an ‘epistemic moment’ occurred during recorded activities of a small group of participants.

An example of Linkograph is shown below. The Linkograph highlights the cluster of nodes that demonstrate many short backlinks related to discussions of materiality in the first part of the discussion *linked to* a change of material selection and a series of forelinks further to discussion of the change in lighting effect. The forelinks in this instance are coded as “Structure” from the FBS ontology, demonstrating understanding of the underlying principle (threshold concept).

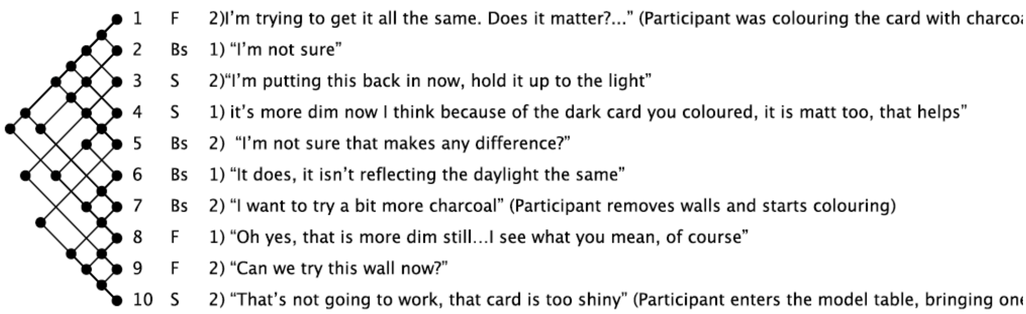

Figure 42 Linkograph generated from Workshop 4

The parsed conversation in this Linkograph includes the following discussion as transcribed:

Workshop 4 Model:Studio – Example: Case Study 3

Tools: Physical scaled model-making in daylit studio space (sunny and overcast variable skies, March, Edinburgh, UK)

Participant 2: "I'm trying to get it all the same. Does it matter?..." (Participant was colouring the card with charcoal)

Coded: F - Function

Participant 1: "I'm not sure"

Coded: Bs - Behaviour (with link to structural idea)

Participant 2: "I'm putting this back in now, hold it up to the light"

Coded: S – Structure

Participant 1: "it's more dim now I think because of the dark card you coloured, it is matt too, that helps"

Coded: S - Structure

Participant 2: "I'm not sure that makes any difference?"

Coded: Bs - Behaviour (with link to structural idea)

Participant 3: "It does, it isn't reflecting the daylight the same"

Coded: Bs - Behaviour (with link to structural idea)

Participant 2: "I want to try a bit more charcoal" (Participant removes walls and starts colouring)

Coded: F - Function

Participant 1: "Oh yes, that is more dim still…I see what you mean, of course"

Coded: S - Structure

Participant 3: "Can we try this wall now?"

Participants 1 and 2: "That's not going to work, that card is too shiny" (Participant enters the model table, bringing one-sided modelling card)

Coded: S - Structure

The characteristics and contexts of these 'epistemic moments' are important as not only were the participants actively discussing the changes in lighting pattern (light to dark) but they were involved in a workshop model making task. The model in this case, along with the card used, can be defined as the "epistemic object", the object that generated the discussions and subsequent learning and evolving epistemic perspective. An 'epistemic object' can take many forms, as a physical or virtual source of reflection, but its translational value is essential to permit new, epistemic connections to occur.

The next Linkograph discussed uses a workshop analysis tool as the "epistemic object". Again, this example proposes that an "epistemic moment" has occurred, through conversation that described understanding of 'luminance'[1], using appropriate terminology for the metric and a theoretical and practical approach to the concept. The conversation was recorded and the key section was transcribed as follows:

[1] Luminance is the measure of the amount of light reflected or emitted from a surface. It is typically expressed in cd/m². It is the measure of light used to evaluate visual comfort and glare in the interior. CIBSE.

Workshop 4 Model:Studio – Example: Case Study 4

Tools: Physical scaled model-making and lighting measurement using Photolux (mobile app), (overcast sky, March, Edinburgh, UK)

Participant 1: "Do you want to take this over here. We'll get better light in it?"

Coded: Bs - Behaviour (with link to structural idea)

Participant 2: "OK, I'll take the photo now" (takes photo using Photolux)

Coded: F - Function

Participant 3: "Did it work?"

Coded: F - Function

Participant 2: "It is taking a while to load…yes. It is showing the top area as really high luminance"

Coded: Bs - Behaviour (with link to structural idea)

Participant 1: "Is it a lot less than the walls?"

Coded: B - Behaviour

Participant 2: "I'm just getting the values for it, where should I press?

Coded: F - Function

Participant 2: "There, on the wall bit" (Examines visual results on mobile phone screen)

Coded: Bs - Behaviour (with link to structural idea)

Participant 1: "On there as that will give the biggest contrast I think…between the top slit and the walls"

Coded: S - Structure

Participant 1: "Oh, look at the luminance for that, that's a really big contrast"

Coded: Bs - Behaviour (with link to structural idea)

Participant 3: "Are you sure we did it right though. I suppose…"

Coded: Bs - Behaviour (with link to structural idea)

Participant 1: Look at that bit… does show really big differences in luminance, that's a bit different there. (Examines numerical, visual results on mobile phone screen again)

Coded: S - Structure

Participant 1: "Do you want to try another view then?...Yes, lets it will probably be a bit different if you can't see that gap. It really is bright the light coming in there"

Coded: *S - Structure*

The "epistemic object" within this study was the tool generating the luminance values, as without viewing the results on the mobile app it would have been unclear as to what the measured values were and conceptually the high and low luminance values may not have been observed or recognised with such clarity. It is proposed that the task of measuring the luminance values of the physical model using the app to record the results required reflective discussion. The continuing task asked for changes in the model to show a reduced contrast ratio. The next task invited participants to question and challenge their existing design but first it was necessary to observe the situation and propose a change in one or more factors contributing to the current lighting pattern.

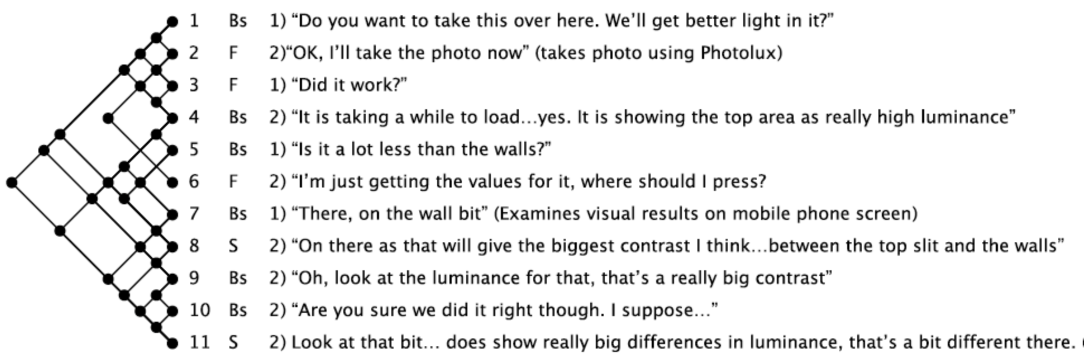

Figure 43 Linkograph example 2

It is important to note the protocols that are coded as “s” for structure. As this code suggests, a “structure” or an “orchestration” (see Chapter 4) of a threshold concept has been coded as happened at that point in the workshop conversation. The node is related to the number of backlinks and, significantly in this case, the large number of fore-inks too. This indicates strong relationships between the previous ideas (as noted in the earlier part of the conversation analysed), informing the new idea generated. It also highlights that the idea was used as a springboard to generate further ideas.

Additionally, the task included within the brief invited participants to reflect on the task and the process of lighting ‘analysis’ at a relatively early stage of the design. The first set of numerical results were provided by the Photolux app as a visual screenshot of the interior space, representing the numerical luminance values placed against the material surfaces of the model. The workshop brief then invited participant groups to assess this image and make changes to the model to change the contrast value, either to increase it or reduce it. This allowed participants to test by trial and error, (as the luminance contrast value would either increase or reduce by the material changes made), or try a change to the physical model informed by an idea of the ‘expected behaviour’ (thereby demonstrating an understanding of ‘structure’ of the concept as the connections between the light, the model materials, the location of each and the viewpoint of the interior space). This task invited reflection and with each required change in the model, demonstrated the reflexive, iterative nature that analysing with daylight should be. Criticos in (Boud, Cohen, Walker, & Society for Research into Higher, 1993), comments that, ”Experience has to be arrested, examined, analysed, considered and negated to shift it to knowledge” and the reflexive methodology that the workshop required sought to achieve this.

It was necessary for the validity of the research to seek information from participants to check alignment of the analysis results and test the experiential value that the participants attributed to these highlighted events. It was expected that triangulation of the data would be possible with the participants and the other workshop facilitators through Focus Group discussions, (refer to Chapter 6 for the set-up of the main research Focus Groups). The Focus Groups were recorded and transcribed (see appendix for transcriptions). Participants were asked a variety of questions including to, “Describe something they had learned about the behaviour of light?”, “Are you now able to change the interior space to change the lighting effect and predict what will happen?” and “What tasks helped you with this?”.

Participants were able to describe “contrast” through “luminance” values, discuss how the sunlight changed the pattern on the interior depending on its location (and they could set this up to test for any time and place), how cloudy skies gave the room a “diffused light feeling” and explained that making a model of the space was more difficult than drawing it “because you had to get the materials right and the light coming from the right place to make it work”. This aligned closely with the discussions transcribed and coded. Findings from the Focus Groups suggested learning happened most often when the participants had to adjust the model (physical or virtual) to fit a new parameter. As an example, one participant commented that making a physical model and changing the colour of a wall to change the “reflectance” was interesting when combined with the Photolux app. Another said seeing the numbers change up or down when they took the image photos on their phone made this very clear. The participants involved in the group conversation from earlier in the chapter commented that in the Model:Studio workshop they thought having lots of materials available to make the models with, helped to give them some ideas of what they could do to change the lit effect.

It was found that all workshop tasks were generative in designing with light with some working methods identified as having particular epistemic value within the contexts explored in this research. It was revealed through the Linkographs that an “epistemic moment” could occur during any part of the exploration process. Surprisingly, it was not concluded that “epistemic moments” most commonly occured at the end of the process, even when the design idea was nearly complete. Where these events seem to happen as a jointly shared event this was most common during the beginning of the process, when brainstorming was taking place, regarding the overall building interior spatial concept. If the events happened at any other time during the workshop this was most commonly personal.

The analysis does however also suggest that group working can be beneficial in creating these epistemic events. The Focus Groups highlighted that the later, personal epistemic events happened when another participant created a physical action, rather than verbalised their thoughts. This workshop study demonstrated that although lighting can be described successfully between peers, it is evident that simply exploring lighting effects without words can also contribute to developing our understanding of the behaviour of light.

The Focus Groups provided an opportunity to initiate the discussion of appropriate design tools to translate and therefore address the fractured relationships between daylighting design and architectural design values within design pedagogy.

The tools that encouraged successful engagement were defined as those that allowed these translations to happen, through transforming or developing understanding of lighting design principles and their application in changing contexts. This was most evident in the acquisition of lighting language and developing expression within design workshops as participants translated *between* formats for example, developing a 3-dimensional physical model into a two-dimensional hand drawing or experiencing a field trip visit to an architectural space prior to the numerical analysis of the lighting using computer software.

Therefore, Linkographs created using the situated FBS ontology for coding can reveal moments of learning or 'epistemic' significance in design protocol studies. The Linkograph must be analysed in relation to the lines of parsed conversations and it is proposed that the number of "structure" and "behaviour" intersecting nodes are critical in finding 'epistemic moments'. It is likely therefore that this use of Linkographs can contribute to examining the learning situations for other fields and contribute to design pedagogy, in particular where this methodology and type of coding is often possible through protocol analysis in design studio contexts.

7.3 The use of a dual-ontological approach through workshop content and methods in real or virtual environments

Within this section a variety of sub-themes are posed as questions to clarify findings relating to the dual-ontological approaches used through workshop content (the threshold concepts or knowledge domains) and workshop methods. This section highlights themes that are connecting or overlapping and also influenced by other complexities such as, "situatedness" Brown, Collins and Duguid (1989), in real or virtual environments, methods used in the workshop and the idea of epistemic design objects assisting design understanding.

7.3.1 How can a dual-ontological approach for daylighting assist spatial designers in learning daylighting concepts?

Initial pilot study workshops clearly differentiated and exposed the ontological and methodological alignment of each method explored. Although each method, whether qualitative or quantitative in nature was seen to progress participants' understandings of the threshold concepts, confirmed through Focus Group discussions, (see Appendix V), the Pilot Study Workshops repeatedly identified that the learning was disconnected through the individual tasks set. It was considered appropriate therefore to include elements of these tasks within the revised workshop set for the main study (outlined in Chapter 6).

However, few connections between the tasks were observed by the workshop facilitators or identified by the participants. This invited new pedagogical approaches to provide dual-ontological perspectives, rather than singular, distinct, conceptual agendas. As the methodological approach sought to eliminate the fragmented design tasks required and encourage dual-ontological methods for learning, the new workshops demanded a developed integration of activities to express these dual-ontologies for daylight at every opportunity. The tasks themselves needed rigorous re-definition to ensure that it was possible to understand and translate between the different perspectives of a daylighting threshold concept investigated through multi-faceted, defined tasks.

Light acquires meaning in architecture relationally, that is, as part of a sequence of luminous relationships. Personal experience is the vehicle for interpretation for both designers and inhabitants. When we can understand the intentions inherent in the way a building is revealed in light, along with the techniques for doing so, then we have the basis for forming both our own intentions and the techniques that realise them.

(Millet, 1996), p3.

The daylighting threshold concepts initially proposed for the pilot study workshop set were re-evaluated to address attention first to 'relational' daylighting concepts as these had shown to be the most successful in explaining the behaviour of light in the pilot studies. Additionally, these were understood to be daylighting concepts where it was possible to provide various methods of achieving a single design intent or demonstration of a concept, whilst overlapping different ontological approaches (qualitative and quantitative). Consequently, the workshop methods designed for the research study workshops sought to demonstrate and gain insights into possible multiple translations. This required the selection and integration of threshold concepts using proposed dual-ontological approaches in each workshop.

Chapter 4 expands on the 'threshold concepts' used in the pilot study and Chapter 6 defines those used for the main research workshops. The threshold concepts each provide fragments of information that uncover the characteristics of daylight but allow for the learning of daylight's expected behaviour in different spatial scenarios through a dual-ontological approach. These were set out as noted below and summarised as follows:

1. **The dynamic nature of daylight, sunlight and shadow**
   Relational Workshop Tasks:

Physically visiting the chaplaincy and defining tasks that required spot measures in the 'Field Trip Visit' workshop ensured participants were aware of the dynamic nature of daylighting. In particular, as participants tested their physical models under real sky conditions during the Model:Studio workshop they discussed the interesting challenge of finding constant numerical measures as the sun was in and out throughout the duration of the workshop. Virtual models were able to demonstrate this threshold concept quickly and simply if the correct command was selected (within the software). Some groups attempted using a physical model to create shadow tracing, but this was a lengthy process and through observing the Model:Studio workshop it was apparent that many groups chose to test only one of two sun locations and moved on to other tasks. As the Model: VE workshop provided quick shadow tracings using different locations, days and times, most participants simply chose to work with this tool.

2. **The differences between daylight, sunlight and shadow and their dependent relationships**
   Relational Workshop Tasks:

The varying qualitative atmospheres presented in visual 2-dimensional images and drawings was the focus of the 'Describe' Workshop. Findings noted that this was successful in building a lexicon for daylighting within a small group and Focus Groups highlighted that using Photolux assisted in focussing on the light in the visuals and the strength of the shadows/contrast. It was noted that some workshop participants commented on the "diffuse" nature of light under overcast conditions. Further most participant groups commented that they became very aware of the textures of their physical model's interior when they took them outside.

3. **The effect of daylight in an interior directly affected by the building form and external conditions**
   Relational Workshop Tasks:

The 'Field Trip Visit' Workshop provided an introductory session demonstrating this threshold concept. As it was only possible, on that day, to carry out spot measurements of the Chaplaincy interior under an overcast sky, it was a successful approach for determining DF but less so with regard to variations due to changing sky conditions. Also, with the real building as a static example, little variation or 'adaption' was possible to test. The physical models allowed much more scope for this and participants were able to test in the Model:Studio workshop many more variations to the designed model and the consequences of each change.

Focus Groups also suggested that the method of using a physical model was useful as it was quick and easy to adapt. Others found the VE model easier to manage in this regard to fulfil the requirements of the brief but only 2 groups proposed the simulated environment method as best. Other groups commented that it was difficult to change the virtual model as it needed "importing again back into the software further to the modification". Significantly, all groups said that it was easiest to remember the meaning of DF through remembering how they had physically demonstrated it through measurements on site e.g. with one group member inside the Chaplaincy and the other outside in the Chaplaincy garden with both providing simultaneous illuminance measurements (using Edenapp or digital light meters). This method was also tested using physical models in the Model:Studio workshop and again, participants said they could remember this metric because they had placed their mobile phones (with sensors) inside the model and outside the model at the same time.

Another task included in the 'Visit' Workshop allowed for further 'experiential' engagement with the daylight in the interior of the Chaplaincy as participants were asked to physically test the no 'no-sky line', see below for this concept shown diagrammatically (P Tregenza & Wilson, 2011), within the Chaplaincy space. Participants were asked to move around the Chaplaincy space, marking on plan where they could no longer see the sky, sitting in the church pews (suggested task height). Measurements of illuminance were taken and demonstrated the daylighting levels dropping off sharply at the "no-sky line". Participants commented in the Focus Groups that this was an easy part of the threshold concept to grasp because, they could physically test if they could see the sky in a real "situated" environment.

4. **The interplay of architectural materials and daylight**
   Relational Workshop Tasks:

Workshop 1 of the main research set prescribed tasks in the brief to discover this threshold concept of the behaviour of daylight on materials and materials on the daylit effect. The methods were based on visual images of daylit interiors and participants drawing representations of these interior spaces (See chapter 6 'Describe' workshop for further information on these methods). Although many participants commented on the connections between daylight and materials within the 'Describe' Workshop it was clear that participants were not yet aware that the interior materials had such a significant effect on the atmosphere displayed.

It was observed in the Model:VE Workshop that participants were able to change the interior materials of the model easily and view the numerical illuminance values almost instantly. However, when viewing the virtual models for qualitative evaluation in relation to the numeric values, it was very difficult for participants to assess this with any clarity as the textural qualities of the renders were very limited. However, from Linkographs of the Model:Studio Workshop conversational analysis identifies clear learning of the same concepts with multiple scenarios demonstrated with this relationship of material interactions with daylight the centre of the conversation (Refer to Linkographs of Model:Studio).

Additionally, Photolux assisted with measured analysis of the appearance and influence of the tonal value of the materials used in the models in relation to the atmosphere achieved and recorded within the model. The concept of luminance contrast was discussed every time Photolux was used and it was evident that some groups understood the "brightness" to be associated with not just the daylight available within the space but also in relation to the reflective properties of the materials[2] used in the space. In the Model:Studio workshop some groups developed this concept further and began explorations into indirect uses of daylight and the effect of coloured materials interacting with daylight in interior spaces (as identified in their physical models).

In summary, the learning situations provided through using a dual-ontological approach for daylighting (in the workshop brief and the tasks) provided scope for designers to learn about daylighting in a relational way.

These workshop tasks became translational activities and could therefore be understood as having a similar connection to Evans' (1986) discussion of "translation" in design. In each workshop, the series of tasks could be defined as the intermediary sources between the qualitative and quantitative aspects of lighting, or, as Evans might define them, "intervening medium," methods such as; hand drawing architectural spaces, evaluating 3-dimensional architectural computer models in virtual environments, writing about an architectural space or making a model of the space.

These workshops provided mostly familiar techniques for the participant group to explore unfamiliar concepts, but these methods and the objects they created as part of the process, encouraged reflection and served as 'epistemic design objects'. It is proposed that this allowed and encouraged translations between qualitative and quantitative ontologies to happen.

Findings from these research workshops have provided the opportunity to initiate discussion and propose appropriate design methods (as workshop tasks), to translate daylighting concepts within spatial design teaching and therefore address the fractured relationships between daylighting design and spatial design values within design pedagogy. This is demonstrated in the next section of the thesis that includes examples of these "translational" opportunities and their practical application through teaching daylighting threshold concepts using 'daylighting design heuristics' in both real and virtual environments in an educational context.

[2] Data sheet – Typical Reflectances of Materials Under Diffuse daylight, p235 (P Tregenza & Wilson, 2011)

7.4 How can an experiential, heuristics-based approach using methods to "see", "touch" and "record" light provide translational opportunities and how can this be approached for learning through situating workshop tasks within real or virtual environments?

Sketching and drawing are spatial and haptic exercises that fuse the external reality of space and matter, the internal reality of perception, the thought and mental imagery into singular and dialectic entities.

(Pallasmaa, 2009), p 89.

Physical expression of daylighting through haptic modelling ('touch') and drawing activities ('see' and 'record') within the workshops was judged to be an essential core element of the proposed pedagogical approach. This aligned with key methodologies as identified in Chapter 4, Pilot Study Workshop findings in relation to design heuristics in Chapter 5 and as discussed above, shaped by alignment with the dual-ontological design processes of Holl and Zumthor (see Chapter 2).

With this methodological underpinning, it was proposed to include specific heuristic processes within each workshop guiding appropriate haptic engagement in each scenario to guide the novice designers. These heuristics were based on those that had appeared in the pilot studies as participant actions and specifically aligned to suit the daylighting threshold concept under discussion for the main workshop. Design heuristics were seen to be an appropriate methodology for investigating daylit spatial scenarios as heuristics are known to, "employ idea triggers that assist in creating concepts using simple prompts" (Yilmaz, Seifert, & Gonzalez, 2010). This understanding was seen to imply that this use of heuristics as "triggers" (Yilmaz et al., 2010) may also assist in the understanding of concepts using these simple prompts to guide participants' investigations.

Much is known about the importance of design heuristics (Finke, 1992) and how they can help with creative design responses, (Studer, Yilmaz, Daly, & Seifert, 2016), (Yilmaz et al., 2010), but there is currently little evidence in their use in design teaching and specifically how novice designers, such as the participants in this research study, can apply them in the learning of new concepts. For example, if a novice product designer is to design a soap dispenser, applying the heuristic, "modify," this provides little direction for exploring potential redesigns (Yilmaz et al., 2010). Yet, *how* to modify the design is not clear for the novice designer who may not understand the implications of one modification over another.

Almost all empirical studies found within the domain of design heuristics of designing were focussed on the development of new creative design ideas rather than assisting in the understanding of new design threshold concepts. Therefore, this research study aimed to take these investigations into design heuristics further investigating using research workshops. Through exploring and recording which specific heuristics assisted learning around daylighting design, and how the provision of selected heuristics affected (or guided) the learning of the selected daylighting threshold concepts, this methodology sought to assist the novice designer.

Using the previous pilot studies as a resource, the conversation analysis of the workshops and the Focus Group discussions, it was possible to identify a distinct list of design heuristics to change the daylighting of a modelled space and determine those physical spatial factors influencing the change in daylighting effect. As it had been found in the pilot study, general heuristics suggesting, ‘carve’, ‘move’, ‘make’ ‘adapt’ and ‘modify’, were not prescriptive enough as they in themselves created “ill-defined” problems (Duffy & Jonassen, 1992), (Yilmaz et al., 2010). These heuristic notions were difficult for novices to work with as a selection of participants commented in the Focus Groups that they understood the task, “that we were asked to carve into the model” but they were unsure “how to modify the model to get the effect they wanted”.

Therefore, in the revised workshops, a list of ‘haptic heuristics’ as phrases, rather than a singular action (noted below) was given to each group with the relevant workshop task. This used the general heuristics of ‘adapt’ or ‘modify’ as in the Pilot Study Workshops but more advice was given in the phrases to guide the necessary smaller moves to achieve this and assist in more successful explorations. Evaluation of the use of these heuristics as a list of actions allowed for assigning their ontological perspective in use through FBS coding (using a similar approach to the Linkographs for coding). Each heuristic was coded as development of the “function”, “behaviour” or “structure” (Gero & Kannengiesser, 2004) of the modelled space. This coding then provided insights into the suitability of each heuristic for novice daylighting designers and the FBS ontological perspective each proposed heuristic aligned with.

Findings suggested alignment between the following heuristics and FBS ontology where in each case, participants' actions were either coded to relate to Function (external variables used to explore an internal interpretation) or Behaviour (an expected action or effect) and, if the participant accepted or expected (through knowledge of the concept) that the design action would be successful, followed then by 'Structure' (an 'orchestration' (Williams, 2010) of the design). This summarised list includes in bold those adverbs found within the conversation analysis from the Model:Studio workshop and in italics additional words added from workshop Focus Group or summary discussions, completing the set.

Daylighting Design Heuristics

Carve a ….. window opening (Function > Behaviour)

- **Larger**
- **Smaller**
- **Wider**
- *Narrower*

To make the daylight/sunlight …. (Behaviour > Structure)

- *More*
- **Less**
- **More powerful**
- **Just a slice of light**
- **Obvious**
- **In one area, the other area dark**

Move the walls, ceiling or window openings …. (or a single element), (Function > Behaviour)

- **To one side**
- **To both sides**
- **To the ceiling only**
- **To sit in a row**
- **To alternate sides**

To make the daylight/sunlight …. (Behaviour > Structure)

- **Evenly spaced**
- **Just light from above**
- **Just light from low level**
- *To block sunlight as a certain time of day*

Make the walls, ceiling and floor …. (or a single element), (Function > Behaviour)

- **Thicker**
- *Thinner*
- **Double skinned**
- **More reflective**
- *Less reflective*
- **Rougher**
- **Smoother**
- **Darker**
- **Lighter**
- **Transparent**
- *Translucent*
- *Partly opaque*
- *Rhythmic*

To make the daylight/sunlight …. (Behaviour > Structure)

- **Stronger**
- **Sparkle on the floor**
- **Shine in between**
- **Reflect off the ceiling**
- **Have a textured effect**
- **Striped**
- *Evenly distributed*
- **Contrast with the shadow**

Adapt the colour of the …. (Function > Behaviour)

- **Window glazing**
- *Window reveals*
- **Ceiling**
- **Walls**
- **Floor**
- *Furniture or contents*
- *Light*

To make the daylight/sunlight …. (Behaviour > Structure)

- **Stronger colour**
- **Create a colour inside the space**
- **A warmer colour**
- *Give indirect colour to surfaces*
- *To see other coloured surfaces differently*
- *To make some architectural details disappear*
- *Increase/Reduce*

Modify the spatial …. (Function > Behaviour)

- **Volume**
- **Proportions**
- **Viewpoint**
- *Relationships to other spaces (rooms)*

To make the daylight/sunlight …. (Behaviour > Structure)

- *Increase*
- **Make the space feel tall**
- **Fill the whole space**
- **Very concentrated**

These lists begin to form appropriate haptic actions that novice designers could take to start to create a specific qualitative daylighting effect. Although relatively limited through the scope of this study these lists begin to suggest a rich source of useful heuristics that can be applied to create expected daylighting design scenarios. This identifies with (Di Mari, 2014) "Operative Design - Catalogue of Spatial Verbs" and "Conditional Design – an Introduction to Elemental Architecture" where heuristics are explored in relation to architectural forms. However, the developed findings in this research study provide one further step. Serving as a design source, these 'haptic heuristics' can guide decision-making relating to daylighting for spatial designers through the selection of the daylighting effect and the consequential design moves required to achieve this.

In itself the novelty of this resource is simply the minimal experience of the 'orchestration' of daylighting within spatial design needed to use this method appropriately. However, when quantitative daylight ontologies are included within this approach (encouraging a dual-ontological approach), the value of this resource tool becomes more obvious. It is possible to define the actions needed to change the quantifiable results using the lists noted previously e.g.

Adapt the colour of the… ceiling… to make the daylight… increase

In summary, actions relating to technical aspects of daylighting design are, as has been discussed in previous chapters, often less easy for the spatial designer to engage with and demand more time and complex tools. However, using these approaches participants were able to collect a series of words, both qualitative and quantitative, to describe daylighting in their own terms and align with their CoP.

Terminology, accompanied by appropriate haptic heuristics, whether prompted or not, was seen to advance learning of threshold concepts to achieve a desired effect or engage with the elements of design affected by it. It was possible to engage with the *quantitative* aspects through *qualitative* heuristic actions. An alternative approach to this translational methodology is considered below, defining the idea of using methods to “see”, “touch” and “record” daylighting in scaled models and real spaces and varying 2-dimensional and 3-dimensional formats through drawing by hand.

7.4.1 How can drawing assist in the exploration of daylighting threshold concepts?

Questionnaires and Focus Group findings noted that participants generally found their daylighting hand drawings successful. Many participants commented that they enjoyed the experience of drawing from photographs, physical scaled building models and real environments and had confidence to explore new drawing techniques through drawing shadow, or the reverse, in drawing light.

In the Describe workshop participants were asked to draw the photographic image of the space they were given using any media they wished. It was expected that through creating hand drawings in the workshops, participants would be encouraged to ‘touch’ light, through the action of drawing, ‘see’ light, through observing as they drew, and ‘record’ light as the media was added to the paper creating a drawn record, based around familiar qualitative ontological perspectives. Further to completing the hand drawn visual, Photolux was employed using the participants mobile phone and sensors to measure the contrast in luminance of the 2-dimensional visual. Some participants recorded these images.

With this exploration into hand rendering techniques it was possible to ‘see’ the contrasting tonal values of vertical surfaces as chosen to be drawn, a qualitative measure, alongside the numeric luminance values, a quantitative measure, using the real-time luminance app, Photolux. This layering of numeric values against the hand rendered drawing provided clear translations between the previously disparate ontologies for light such as (qualitatively) how dark or light we can expect an interior space to feel with a given (quantitative) contrast ratio or set of luminance values. The relationships between numerical luminance values and a lit scene were therefore revealed through these lighting contrast ratios.

This method of drawing was encouraged during both the Describe workshop and Model:Studio workshop. In the Describe workshop these drawings described the photographs of the space (as provided within the brief) and then in the Model:Studio, they demonstrated a visual representation of the built scaled model (of the same building case study). See below for an example set of the visuals generated.

All the drawings generated in these workshops were tested with Photolux to determine variations and/or matching contrast values perceived by the eye against the numerically measured. It was found that the threshold concept of uniformity/contrast/diversity was explored successfully using hand drawing techniques with an added layer of numerical information. Unfortunately, Photolux digitally renders the spaces with false colours. This representation may be appropriate for some applications but much less so when trying to understand darkness versus the lightness using interior finishes.

Further to findings within the pilot study workshop set where participants had used Pro Markers/Pantone Markers to create contrast of light and dark in their drawings successfully this technique was encouraged and developed within the Describe and Model:Studio workshops. Participants who attempted this method of drawing to visualise lighting contrast were able to discuss the differences in light:dark and discussed ratios. In the workshops I sought to encourage translations between qualitative methods and quantitative methods to measure the hand drawings. Photolux was therefore introduced to create a luminance map of the drawing, giving numerical measures to the hand drawings. Therefore, the translations made explicit through this method were those relating to lighting contrast concepts to numerical ratios. It was encouraged that participants used grey Pantone/Pro Marker pens (Cool Grey or Warm Grey) to create areas of light or dark on the page corresponding to the depth of pen layers as a relational scale.

When these drawings were photographed and analysed using Photolux against the physical model the difference in lighting values between the hand technique and the digital photo numeric analysis was negligible for up to half of those drawings tested in this way. Lighting contrast had been shown and understood successfully using basic, yet familiar hand drawing tools (qualitative) with relational, numerical (quantitative) values. Participants found this challenging but rewarding as a significant number of participants had judged the contrast values with reasonable accuracy.

This finding goes against other empirical studies that suggest the human eye is not skilled at quantifying lighting ratios (Christoph F. Reinhart & Weissman, 2012), (Boyce & Smet, 2014), (P. Tregenza & Mardaljevic, 2018). It may simply be that the range of luminance values this study used were limited because real spaces were not used, other than during the Field Visit workshop. Additionally the Model:Studio workshop tasks required limited comparisons; a case study photograph of interior to drawing of the photograph, or a case study photograph of interior to photograph of the scaled physical model (not a real space) and a photograph of the drawing of the physical scaled model to the photograph of the scaled physical model (not a real space) to the case study photograph of interior. In addition, in all of these scenarios the eye had plenty time to adjust to ambient lighting levels.

During the Field Visit workshop (Workshop 2), some participants noted the comparison of their drawn images of the space with the same view taken on their mobile phone camera using Photolux in the space, however, as this was the first workshop using Photolux for some, comparisons of the measured values to their own drawings was not emphasised in order to avoid discouraging participant engagement through lack of alignment in results. Further investigation into this type of scenario would be fascinating and clarify if this approach is useful in other situations and applications. This finding was significant for its success in translation of a quantitative based lighting concept. Also, this method allowed translations to work in reverse, to allow a given contrast ratio to be realised visually. Bryan Lawson (2004) comments that, “What a designer really needs is to have some feel for the meaning behind the numbers rather than precise methods of calculating them”, and this dual-ontological method for contrast with luminance mapping aligns exactly with this aspiration for a broader epistemological approach. Significantly, through the research workshops, participants demonstrated that the familiar task of drawing could be used as a successful tool to draw lit spatial effects.

The visual data collected from the workshops was primarily participants’ own recordings. This had been initiated to reduce the researchers’ biased perspectives dominating the workshop results and findings. The collected data was sufficient for this study. However, although the importance of visual and verbal recording techniques used to log participants' process was emphasised each week, many participants became so involved with the tasks that they simply forgot to record aspects of their design process through photographic recording (as clarified in the Focus Group sessions). Therefore, although a substantial amount of verbal information was recorded, as this was carried out continuously throughout the workshop at specific tables, the analysis process had less dense information regarding visual outputs such as photographs of models or drawings. For future studies of this nature I would propose that 10-15 minute recording reminders are set to ensure that the data collected is much more balanced. Further insights may be possible with this more rigorous, though significantly more obtrusive approach, if the resulting data is not then jeopardised by the required intrusions into the flow of activities as a result of this recording process.

7.4.2 How can field visits assist in the exploration of daylighting threshold concepts?

Andersen comments in D&A Magazine (Andersen & in Schoof, 2017), that the "experience of actual built space allows us to better understand the connection between the numbers and actual conditions in terms of glare, illumination levels, views out and other daylight related aspects". Although there is no empirical evidence within design pedagogy publications to confirm this conclusion in educational contexts, with Andersen's wealth of teaching and research experience in the field alongside findings from this study, it is reasonable to propose this experiential approach is successful for novice designers. This research study highlights field trips in particular as assisting the development of translations of daylighting threshold concepts in virtual daylighting environments through associated, previous, experiential understanding. These findings correspond with general learning concepts proposed by (Boud et al., 1993) regarding learning from experience as "new ideas and new experience link to previous experience".

The 'Field Visit – Workshop 2' visit to the Chaplaincy space was seen to be successful in two respects: 1) introducing workshop task activities inviting translational recording opportunities between both quantitative lighting metrics/numerical values and 2) encouraging qualitative visual representations, motivations and reflections of the daylighting of a real space.

Findings from the pilot study workshop set suggested revised sequencing of the workshops to yield improved learning opportunities. Therefore, the field trip ‘Visit’ workshop to the Chaplaincy was scheduled to occur prior to the virtual environment workshop (for numerical analysis of the daylighting using computer software) to allow participants to evaluate the real space prior to working with it in the Virtual Environment (VE).

VE provides a learning environment to test an active hypothesis, and therefore can provide a powerful medium for learning. However, the pilot studies within this research study and from a review of literature within the field of spatial design (Attia, Beltrán, De Herde, & Hensen, 2009), (Attia, Hensen, Beltrán, & De Herde, 2012), (Iman, 2015) indicated that the complexity of numerical input and output daylight values were significant in the VE. These numerical values, alongside the necessity for accurate specification of the spatial design material attributes, were known to create barriers to the success of this learning method.

Yet, existing research around this topic promoting simulated environments as an appropriate pedagogical approach to learning quantitative building analysis is plentiful such as e.g. acoustics (Jaramillo, 2015) and environmental engineering (Attia, Gratia, De Herde, & Hensen, 2012), (Tumini & Garcia, 2014), (Chao et al., 2017). The sequencing of educational workshops to allow virtual testing of active hypotheses before application of concepts in real scenarios has been tested and validated before, this is not a new approach. However, in this research study it was proposed to visit the real space first, then enter into the VE realm for comparison. It was expected that this approach would assist in reducing the difficulties of understanding the quantitative methods demanded in the VE.

The on-site workshops (see chapter 6 ‘Field Visit – Workshop 2’ section for full details) were carried out first, inviting experiential methods of measuring and quantifying daylight whilst also representing the qualitative experience using visual methods before additional experiential learning approaches within the VE.

This experiential evaluation of the real space successfully and subsequently informed daylighting design activities in the Model: Virtual Environment workshop. As the real space and its associated numerical measures had previously been verified on a real site as part of the Visit workshop, this new sequencing of the workshops demonstrated an increased ability for participants to reflexively self-correct any erroneous translations in their daylighting analysis in the virtual environment. Participants were therefore significantly more aware of their daylighting analysis errors in the virtual environment and were able to predict what the numerical values should be in the virtual environment model following the site visit. In design practice this situation is, of course, rarely possible to achieve, as the spatial design has often not yet been realised on site. However, with some practice measuring and evaluating a series of different site contexts it is plausible to suggest that this growing numerical awareness of real scenarios can improve the prediction of numerical output values and appropriate inputs for new design contexts. Even if this is just simply an appreciation of the effects of different material surface reflectances on daylighting behaviour within a space.

In conclusion, these findings correspond to published work demonstrating case-based design approaches to design (Schank, 1982; Kolodner, 1993) where previous experience has been shown to be used as building blocks, adapted to solve problems in new situations (Maher & Gomez de Silva Garza, 1997; see also Klein, 1998; Ball et al., 2004; Scott et al., 2005). This finding also corresponds with learning concepts proposed by (Boud et al., 1993) regarding learning from experience as "new ideas and new experience link to previous experience".

It is therefore understood that field visits to architectural buildings/spaces gives designers the opportunity to use these experiences to assist in the design of new scenarios and compare other scenarios previously experienced. This research study proposes that daylighting experiences can be called upon to help translate as necessary in new contexts.

7.4.3 How can the use of physical scaled models assist in the exploration of daylighting threshold concepts?

"Experience indicates that it is essential for architects to personally appreciate the luminous environment of a space and to compare several solutions quantitatively and qualitatively. This intuitive appreciation obtained by scale models and the 3D perception of the light distribution cannot currently be obtained by use of computer simulations."

(Bodart, Deneyer, De Herde, & Wouters, 2007), Introduction.

Dual–ontological approaches were developed into workshop methods to build in familiar studio methods and 3-dimensional thinking about daylight, further to the Visit workshop and/or the Describe workshop. Mitrovic (2013) comments that, "3-dimensional thinking is the core skill in architectural work". Therefore, with the spatial design participant group for this research study it was intriguing to consider daylighting design and question if this included a 3-dimensional understanding of daylighting?

This need for spatial designers to experience the 3-dimensional properties of the space indicated the use of physical models would be worth investigating. The dual-ontological approach demanded different perspectives with which to experience and understand the daylighting in the physical model, through the use of side-by-side experiential scale model-making (encouraging 'touch') and lighting measurement techniques ('see' and 'record') to encourage simultaneous qualitative and quantitative perspectives. This was practically achieved by building physical scale models of the case study spaces in combination with using measurement apps (Edenapp for DF and Photolux for luminance) to take "snap shot" contrast luminance maps or illuminance values of selected views into these physical scaled models (as outlined in chapter 6). Measurement tasks continued whilst participants adapted the model to change the behaviour of daylight to suit specific task requirements, following heuristic suggestions. Using scaled, physical architectural models in the workshops the participants were invited to consider, "the [3-dimensional] space the building forms as the negative of the building itself" (Mitrovic, 2013), filled with light.

The physically (scaled) model of the interior space as modelled was selectively carved into by the workshop participants to define the relational concept of external daylighting influencing directly the interior daylighting effect. However, there are obvious difficulties with the accuracy of results when working with models. It was clear that the physical models created in the workshops allowed for discussion of not only the overall effect of the lighting in the interior caused by the ‘carved’ external walls ,but also the effect of light hitting and reflecting back from each internal surface. Bodart (2007) and (2017) comments that material choice for a physical model, in particular, can have significant effects on the accuracy of the representation of the lit space and the measurements taken. Bodart and Deneyer’s research (2007) indicates that an “overvaluation of the reflection factor can lead to large errors”.

[If] the vertical wall has a reflection coefficient of 50 % and if the scale model has white walls (ρ=85%), the measurements made in the scale model can overvalue the results of about 150 to 200 %, for a point localised at the far end of the room.

Bodart (2007), p.5.

If quantitative measurements are required, they therefore recommend that the materials selected for the model are as close as possible to the full-scale material's reflection coefficient (Bodart and Deneyers, 2007). If the objective of the study is to evaluate the visual impression felt in the room, it is the colour of the scale model material that will be as close as possible to the colour of the full-scale material. However, the participants within this research study also noted that the textures of the materials selected were important too for qualitative analysis (see image below).

To further encourage investigation into the effect of the daylighting design on the interior surfaces of the model, the Model:Studio workshop included a task that required hand drawing the interior space as viewed in the scaled model, encouraging considered translations through a change of format and perspective. As a reverse of this process, a further workshop task required the creation of a 3-dimensional physical model into a two-dimensional hand drawing. This task sought to highlight the effect of the daylighting on the 2-dimensional spatial surfaces and adjacent surfaces in relation to the overall 3-dimensional view. Significantly, the exploration of these methods in the workshops demonstrated the translations that changes in format requiring haptic, heuristic engagement can expose and provide for novice daylighting designers.

Participants in Focus Groups commented that it was possible to describe the daylight through drawings most successfully and confidently when attention was focussed on each surface interacting with the light (required to create the orthographic projected view). This elemental method of ‘see’ing and ‘record’ing invited explorations into lighting texture, contrast and the homogenous lighting effect possible through diffuse daylight. 7 out of the 9 conversations analysed from these workshops included comments demonstrating focussed, detailed design considerations and comments noting the interactivity of each surface with the light. Further, Bodart's model making guidelines were discussed with the students and they grasped the importance of their choice of material with all discussing this in their groups before they started making the models. This was also noted in the Focus Groups by some participants as an important point about daylighting that they had not considered before, indicating an epistemological change in perspective. Participants were encouraged to test alternative materials (tone, colour, porosity, specularity, texture) within the models and evaluate the effect of these changes on the atmosphere of the interior space to provide different reflectance properties and new atmospheres in the physical model.

Clarity in the accuracy of the measurement results using Photolux and Edenapp were also an important element to grasp. This difficulty was relational in approach as any artificial light used in this basic studio set-up would not provide an equal amount of light as the sky and, material reflectances were simply measured by eye or calibrated using the worksheet notes. This was highlighted to participants by taking the models outside for additional, comparative measurements and asking the participants to suggest how the accuracy of results could be improved. Further, the threshold concept was understood to be less about the absolute values and more about the principle of daylight interacting with materials. As participants used artificial lighting sources, such as their mobile phone lights (if not testing their scaled models externally) and physically shifted the light source into different positions during scaled model making explorations, conversation analysis revealed an increasing awareness of the lit effect in the modelled space *in relation to* the light source.

Investigations into these relationships were encouraged within the Model:Studio and Model:VE workshops as participants were asked to change the contrast ratio values they had obtained for the physical scaled model and to increase and/or reduce them through manipulation of the model. Participants commented in the Focus Groups that they "understood how some of the materials worked with light better…I can imagine it now I think". However, the measurement of absolute illuminance levels or luminance was less successful. Although participants were able to engage with these measurements, it was often unclear whether they understood the fundamental daylighting concept in that the values they were achieving were not realistic or accurate numerical measures due to the testing taking place in interior studio spaces. Therefore, it is proposed that although the accuracy of results was a significant limitation, some participants were aware of this, and crucially, learning was still possible and the model making productive in this regard, but particularly when modification of an existing situation was required.

'Record'ing and 'see'ing these relationships revealed the basis of the Daylight Factor, a recognised lighting metric, measured as a ratio of indoor illuminance to outdoor illuminance (refer to Chapter 2). This approach, using physical model or space measurements identified relational numeric values and the changing sky condition influencing the interior atmosphere. It also highlighted for many participants the imprecision of the average Daylight Factor calculation in relation to variations in sky conditions through changeable weather patterns, building/room orientation and fenestration locations.

The relationship between temporal external illuminance affecting internal illuminance became clear when measuring both, simultaneously, using Edenapp[3] within a physical model or a real, built space. The differing contexts of i) external sky condition and ii) interior architectural condition could be observed simultaneously and evaluated against each other. Therefore, although DF and contrast ratios were successfully tested, (even with significant errors due to indoor location), as they are both relational values they were still found to be useful methods for exposing the underlying factors of the selected threshold concepts.

Testing sunpath and sunlight penetration using physical scaled models outdoors, although expected to be more successful due to improved accuracy using the real sky condition, revealed other problems in approach. Workshop tasks required illuminance values to be measured and DF values repeated. Under real sky conditions the results fascinated the participants as they found it difficult to find a stable measurement as the dynamic range of measured sky illuminance values were made explicit. Further, the inaccuracies of DF became evident when testing outside as participants tested the models from each orientation and found the DF results to be different. This indicated a useful method of considering DF, rather than simply discussing the inaccuracies of the measure these were tested physically using experiential methods.

[3] Edenapp, founded at the University of Edinburgh - https://msa.ac.uk/edenapplabs/

However, with regard to sunlight and sunpath tasks, testing the physical scaled models outside was challenging for many participant groups. A tilting table drawing board was set up to place the model upon, serving as a basic heliodon. However, it was found that although shadows became apparent in real sunlight and the notion of the transience of daylight (and the appearance of sunlight) was discovered for many through use of the app meter, the realisation of the actual sun angles was challenging. The logistics of moving the model table (representing the position of the ground in relation to the sun to suit the testing of a specific latitude, day and time) was perceived to be an unfamiliar task. Most groups found this method difficult to comprehend as the ground base was no longer in a familiar position but required to be tilted to correspond with the angle the sun was coming from in order to achieve the desired date and corresponding sun angle.

Overall the learning of some threshold concepts became clearer with the use of scaled models. In the Model:Studio workshop the use of physical models allowed for successful trial and error attempts by participants to achieve set daylighting goals.

What appeared to be more difficult for participants to respond to successfully were the challenges, included in the brief, to adapt the *qualitative* atmosphere of the interior space of the physical model. Within this task, it was observed that participants, although entering into substantial amounts of discussion, were unable to agree on the qualitative atmosphere achieved through model manipulation. Some group members commented in the Focus Groups that they had “run out of time”. This confirms that for many the daylighting design challenge given belonged to an ‘ill-defined’ domain with loose boundaries and subjective, experiential reasoning without one, specific, answer to the problem. Significantly, participants spent more time questioning and discussing the qualitative challenges than the quantitative. As soon as the required numerical lighting values had been achieved, participants moved on quickly to the next task, rather than test additional alternative approaches for achieving the quantitative measure.

This finding reveals insights into the differing ontological perspectives of qualitative and quantitative daylighting design. Lawson (2006) attempts to explain the different perspectives of design demands in relation to these differing ontologies through his research into design motivations; “Perhaps it is because design problems are often so intractable and nebulous that the temptation is so great to seek out measurable criteria of satisfactory performance”. p71. The measurable criteria were clearly set-out in the quantitative tasks within the Model:Studio workshop brief. With the qualitative tasks requiring qualitative definition, without measurable criteria this was considered a more difficult task. Those groups who completed the tasks with time to spare were asked to repeat the measurement of their models, comparing the qualitative effect they had created in the physical model and defining this by numerical measures using the apps (Edenapp and Photolux) to attempt to find further ‘translations’.

In conclusion, the behaviour of light interacting with different surface materials, textures and forms can be revealed through physical model making with some success if the materials for the model and the test location are well considered. Also, a qualitative analysis of the space is possible if the colours and textures of the materials are included within the scaled physical model. Physical measurement of relational numerical metrics such as Daylight factor can assist in the understanding of daylighting concepts, their purpose within the design process and their shortcomings in relation to the qualitative ambience of a space if this dual-ontological approach is used.

7.4.4 How was the use of virtual environment models successful in the exploration of daylighting threshold concepts?

Participants were able to build on their previous experience of visiting the space, the Visit workshop, and compare this “situated” (Duffy & Jonassen, 1992) experience with their new virtual environment (VE) workshop. They were not able to compare the virtual space created in VE with the one they had experienced. New connections were therefore not only created but allowed to be tested in a comparative way. The Model:VE workshop highlighted benefits in visiting and experiencing the real space prior to working on a virtual model of it, because the numerical results could be compared against each other and the qualitative experience of the real space could be remembered as the quantitative calculations were carried out. The following findings illustrate this methodology as a pedagogical approach.

The literature review suggested that the tools currently available for spatial designers designing with daylight in virtual environments were underused because they were not accurate enough, advocating that designers require more advanced (in terms of processing speeds), accurate tools (Attia, Gratia, et al., 2012; C. F. Reinhart & LoVerso, 2010). This did not appear as a key finding in this research study.

Instead, the Pilot Study Questionnaires and initial Focus Group discussions highlighted that many daylight analysis tools were considered too time consuming, in operation and training requirements, or too complex to use. Some participants noted that they were required to build new virtual building models to test the space for daylight or existing virtual models needed refinement and removal or added information which was too time consuming. Additionally, Pilot Study Workshops confirmed that the terminology needed to understand the requirements of the input values was not easily understood.

Findings from the research study, gathered from Focus Groups, revealed that selecting the input values for working within virtual environmental design software in the Pilot Study Workshop and ‘Model:VE’ Workshop was difficult. However, when participants realised that this related to the visual contrast scales they had used in the ‘Describe’ Workshop the quantitative input values were then easier to propose and adapt. In the Pilot Study Workshop, this pre-existing knowledge to assist translation of the task was not available to participants, relying only on their past experiences as a novice designer. In the ‘Model:VE’ Workshop, only 4 groups out of 35 initially realised that a comparison of quantitative results was possible between the ‘Visit’ Workshop and the ‘Model:VE’ Workshop.

However, once this had been pointed out to the full group by the researcher, most groups chose to compare and evaluate their answers. In the Model:Studio workshop, participants were able to reflect on the results of the virtual analysis and gain further insights into the translation of these results between lighting quality and quantity. Further, using the virtual model participants had to be guided in their option of changing material surfaces of the virtual interior model through the ‘Daylighting heuristics’ page in the workshop briefing booklet. This design option, to explore the interior materiality, resulting in new luminance and illuminance values for the space was not immediately apparent as an approach to creating a different atmosphere for the interior space within the VE. In the Focus Groups, some participants commented that tools were hidden and they weren't sure about "changing the settings in case something wrong happened". With a lack of confidence in manipulating the software some participants were not confident enough to make bold changes to the material settings.

In conclusion, the difficulties noted here clearly provide insights into the underuse of VE software for daylighting within spatial design practice. The interface does not clearly define appropriate parameters for numerical input values and this is an issue that now needs addressing. Further, if we consider the design process and the use of lighting analysis software within this approach we can understand why spatial design practitioners shy away from frequent engagement with these tools. They demand significant areas of design decision-making to be in place to allow reasonable and appropriate input values to be provided. Literature addressing these issues specifically advocates the development of an ever-increasing range of new software tools that propose strategic steps for analysis (Andersen, 2008), (Davoodi, 2016), (Fernández, 2012) to fit a series of analysis steps through pre-defined optimisation goals. However, the studies carried out by (Cross, 2011), (Lawson, 2004), (Lawson, 2006) highlight the iterative process of design and the fluid nature of many spatial design projects with changing priorities, and this is still seen as a current challenge in light of the research findings from this study. However, in an educational context, it is clear that any developments to achieve software that novice designers can use to demonstrate quantitative parameters for daylighting and the relational strategic design decisions that define them, balanced with other design priorities is seen to be very beneficial "experiential' learning. Lawson proposes, "As a designer you need to know the kinds of changes that can be made to the design which are most likely to improve it when measured against the criteria. It is thus more a matter of strategic decisions rather than careful calculations" and workshops in this research study using physical models or virtual environment modelling have both been shown to be successful in this regard.

The next section discusses the idea of "situatedness" further and focusses on the use of these methodologies within the context of the educational design studio.

7.5 Was the workshop format a useful research methodology for this study's context and aims "situatedness"?

Exploratory workshops were chosen as a research method to investigate pedagogical possibilities encouraging a dual-ontological perspective in novice spatial designers. It was proposed that methods to modify/expand the mono-ontological (or currently disconnected/limited) perspectives found in the participant groups (CoPs) taking part in the pilot studies could be found. This was investigated through evaluating workshop methods, demonstrating and following methods of designing that embraced a broader, integrated epistemic approach.

The majority of the workshops were situated in the participants' design studios or computer labs. Other non-familiar spaces were introduced including the University of Edinburgh Catholic Chaplaincy, used for a field trip, the Visit workshop. The research workshops were carried out over a period of three years (including pilot studies) in educational settings to provide data to allow year-on-year comparisons where practical and, most importantly, indicate spatial design students' current and developed understanding of daylight.

Findings from this study consider workshops to be a successful approach as they provided an opportunity to trial new methods of working with daylight in spatial design contexts with novice designers, who are less experienced in working with daylight but have both the time and inclination to learn new design knowledge. Further, the workshops also allowed recording and evaluation of groups of participants' daylighting design ontologies and epistemologies through approach, creative actions, visual representations and descriptive language in a controlled yet familiar, studio environment. It was found that the educational setting provided an appropriate environment to test these specific scenarios as it could be carefully controlled, with repeat workshops to challenge findings with alternative participant groups. This setting also provided an opportunity for suitable benchmarking of results with participant continuity over the length of the research study.

A brief evaluation of this research methodology allowed for insights into the impact of researching student participants in educational research workshop environments of this nature. It emphasised the importance of ethical considerations, including recording of the participants' work, a significant factor arising directly from this type of research design. Although permission forms were handed out and signed by all participants, I identified the need to explain the participants' relationship with myself as workshop leader. As a design lecturer in the immediate context that the workshops were taking place, it was important to clarify that any results from workshop outputs or verbal discussions would not be assessed to improve authenticity of the results. To ensure this was clear to all participants this was announced at the beginning of each workshop.

Moreover, understanding of the workshop aims, although often subtly presented at the start of each workshop, to avoid stifling participants' explorations, was always included within a full group discussion summary at the end. Participants taking part in the Focus Groups claimed that this was very useful for ensuring they had understood the aims of the workshops fully. For some this resumé provided insights into alternative methods for achieving results similar to their own and a further translation of the threshold concepts.

7.6 How can lexicons develop translational activities and advance understanding of daylighting in novice spatial design students?

The methods that encouraged successful engagement were defined as those that allowed translations to happen between qualitative and quantitative, through transforming or developing understanding of daylighting threshold concepts and their application in changing spatial contexts. This was most evident in the acquisition of lighting language and developing expression within design workshops as participants translated *between* formats for example, developing a 3-dimensional physical model into a two-dimensional hand drawing or experiencing a field trip visit to an architectural space prior to the numerical analysis of the lighting using computer software.

It was found that through participating in the designed workshops, participants' verbal phrases to describe daylighting design evolved and expanded. The use of daylighting vocabulary notably increased through participants attending and engaging with the weekly workshops. The evaluated research data highlighted that development of the understanding of the proposed daylighting threshold concepts was evident through the recorded activities of participants, corresponding with an increased acquisition of lighting language (see Describe Workshop participant sheet in Appendix V).

Further, group discussions using design vocabulary relating to daylighting strategies became a larger component of the overall activity discussion. Even though technical lighting terminology increased only marginally in the workshops, discussion of daylighting and lighting generally became appreciably more integrated into the holistic discussion of the workshop activities. Consequently, this demonstrated that the proposed methodological aspiration for daylighting to be viewed as a holistic part of the overall spatial design, could be encouraged through participation in the daylighting workshops as explored in this research study.

The manipulation of physical scaled models in this research study focussed upon behavioural interactions of daylight with the spatial composition and materiality of the models, rather than formal tectonics based architectural exploration, found in interior design and architecture studios. The language participants used was associated with the community within which they felt they belonged to within the design workshop.

(Participant 1) I never thought concrete could be shiny but it is in this picture…it looks like shuttered concrete, maybe it is wet…is it outside?...yes!

(Participant 2) It must be, it's light shining on wet concrete…it must be the sun shining in on the walls.

(Participant 1) Where do you think the sun is to get into the space like that?

This short conversation highlighted two key aspects:

First, participants used language familiar to their group that may have had a different meaning or context outside the design community. The words "shuttered concrete" could be considered to be specialist language used within spatial design contexts but could also, more importantly, be understood by the context of the "community" within which it was observed in this situation. The use of any expression describing the lighting effect is familiar language and not technical language. As the conversation progressed, it demonstrated that daylighting can be described successfully between spatial design student peers. Further to evaluating the data from the 'Describe' Workshop, it was clear that descriptions of the lighting atmosphere and comprehension of technical principles became richer in meaning and developed more comprehensively through peer discussion as participants added more lighting descriptors to their worksheets after the group discussion.

Second, language describing the lit scene almost always included details of the space itself; materiality, volume etc. Consideration of materiality *with* light was evident as it occurred in the same sentence. Lighting was not discussed as a separate element but how it applied to the heuristic in action. The Model:Studio workshop provided noticeably less use of lighting descriptors than the previous Describe workshop but significantly more discussion of design heuristics – the 'actions' carried out. Although this analysis implied that the Workshops had provided methods of increasing daylighting vocabulary and a list of heuristic actions that applied specifically to daylighting design were assembled, it became clear that findings emerging through the analysis of connected ideas was significantly more important and with more far-reaching implications.

As a record of learning, workshop participants from Groups A + C created lexicons for daylight as the set of workshops progressed (See Appendix VII). Additionally, participants were given time at the end of the set of workshops to work on and complete this task. These lexicons in the form of sketchbook diaries, provided a means of exploration in the search for flexible, adaptive expression of lighting ambiences, with visual and textual translations. In the 'Lexicon' Workshop(s) participants developed translations of daylighting concepts into their own words or visual representations as understood by themselves. Some work emerged as defining daylighting terminology with real skill, others were less articulate and vague in their approach. Those that contributed their sketchbooks for analysis had clearly built up their Lexicons over a period of weeks and had actively engaged with these tasks. Findings demonstrated that this lexicon task was particularly revealing, presenting a challenge for most participants and identifying lingering issues with terminology of metrics. However, significant understanding was demonstrated in many of the subtle visual representations and descriptors.

These lexicons provided evidence of an increasing formation of lighting language through reflexive actions, experiential knowledge and visual expression. They also provided examples of translations and alternative perspectives for lighting terminology for other workshop participants, with further insights for researchers into appropriate visual representations of technical daylighting vocabulary for the Community of Practice studied.

7.7 Summary of findings

The findings demonstrated that some tools and combinations or sequences of tools encouraged valuable translations to occur between the differing daylighting ontologies. When presented and tested in the workshops, these tools emerged most commonly as simultaneous, dual methods that allowed re-presentation of technical lighting language (textual or numeric), through visual or textual expressions. Methods were explored to find how these distinct ontologies (qualitative and quantitative) can be brought together through methodologies that assisted “designerly ways of knowing and thinking” (Cross, 2011), such as through exploring designers’ iterative processes, sketching and making, aligning with familiar approaches currently used by architectural designers in professional practice and educational contexts. The workshops confirmed that these heuristic approaches were beneficial for encouraging workshop participant engagement and development of participants’ understanding of selected ‘threshold concepts’ straddling qualitative and quantitative data.

This research study therefore suggests that the educational methods to invite authentic understanding of the particular phenomenon of daylight are critical, valuable and necessary. It is proposed that an understanding of, and the ability to predict lit ambiance, cannot be disregarded in architectural communities and educational establishments in favour of tools that only allow or prioritise numerical building design energy output data sets or ‘optimised’ solutions. These existing methods require little engagement or skill in their creation and provide no demonstration of authentic complexities of the phenomenon of lighting in their interpretation. The design tools used for the analysis of daylighting in spatial design contexts currently generate unrecognisable data for spatial designers (refer to Chapter 3), as outputs give little indication of the architectural space and the contributing factors directly affecting the results are hidden within complex scripting. The understanding of this digital data requires translations into ‘designerly ways of knowing’ (Cross, 2011), familiar design processes, to ensure intentions are understood and the ability of architectural designers to understand and predict of lighting ambiance does not become a lost skill or lose relevance within spatial design values.

> *As long as educational frameworks relegate the emotional and experiential to the place of a supplement, then our design processes will continue to unconsciously promote environments of thinness and superficiality.*
>
> *(Teal, 2010), p. 8.*

It is therefore proposed that these tools, providing only quantifiable data (with poor visual representations), are in themselves ‘out of touch’ as they do little to assist designers with the prediction of important insights into lit environment ambiances that relate to increasing understanding in the field of physiology and psychology of the visual and non-visual effects of light. This research study seeks to challenge the exclusive use of either method, whether qualitative or quantitative, for the understanding and representation of daylit interiors. Either methodology used in isolation encourages the cultivation of design ontologies for light that are unbalanced. Instead, this thesis proposes that design educators can rise to the challenge of presenting and demonstrating contemporary complex understandings of daylight, simultaneously through both qualitative and quantitative approaches. If the demand for metrics to predict the energy value of daylight continues to grow, this mono-ontological perspective of daylight may demand more authority. Yet, armed with suitable translational methods and daylighting language the epistemological perspective for daylighting can be a more holistic one, thereby successfully accepting the necessity of the quantifiable, whilst attaining the qualitative objectives alongside.

Epistemic moments can and should be encouraged in educational situations to refine and expand novice spatial designers’ daylighting knowledge. Epistemic moments defined points in the design process when new understandings occur in relation to the concurrent description of the physical task. Coding of these data from the Main Research Workshops has allowed the opportunity to initiate the discussion of appropriate design tools to translate, and therefore address, the fractured relationships between daylighting design and architectural design values within design pedagogy.

Epistemic objects are diverse yet many are appropriate and useful. In particular, physical models act as epistemic modulators, changing theoretical and physical dimensions. Heuristics to apply when working with physical models in daylighting contexts have been collated and, working as guides to novice designers, may provide appropriate actions to adopt to solve specific daylighting requirements for both the ambition of the qualitative and quantitative design outcomes.

Although much of the literature reviewed proposed that daylighting design necessitated specific analysis techniques, the importance of the method of conceiving and developing the daylighting design ideas within the whole building design process became increasingly evident as the research study progressed. If daylighting design is to become part of the holistic design process it must be accepted within this messy discourse and allowed to make connections to other parts of the building design that can be evidenced in the final realisation of the design. As building design projects are complex, with many issues to consider simultaneously (Cross, 2011), (Spiro in (Duffy & Jonassen, 1992), the methods to work with daylighting design must adapt to fit within this way of working. These methods cannot demand more time than any other part of the design process and, crucially, must fit well within the familiar design processes used by architects and interior designers.

This work is unique by showing developing understanding of daylighting threshold concepts across groups of novice designers, using distinct measures (language conversational analysis in Linkography, tracking data about epistemic moments of learning, qualitative responses from novice designer participants) and responding to contemporary pedagogical challenges (emergent design demands, interaction with real and virtual spaces and real and virtual heuristic methods). The findings explicate the opportunity to continue to use these nuanced designerly ways of knowing within daylighting education, to drive epistemic changes in spatial designers' perspectives towards daylighting and exploit translation tools available to spatial designers to converse between and merge qualitative and quantitative ontologies of daylight. Further, as findings demonstrate, the use of Linkography has provided insights into epistemic spatial learning experiences and the potential for this in other areas where the FBS ontology can be applied. It may not simply be the analysis of daylighting design workshops that can benefit from these findings.

Chapter 8 Conclusions

8.1 The emergence of a dual ontology for daylight

> *We must consider space, light, colo[u]r, geometry, detail, and material as an experimental continuum. Though we can disassemble these elements and study them individually during the design process, they merge in the final condition, and ultimately, we cannot readily break perception into a simple collection of geometries, activities, and sensations.*
>
> *(Holl, 2000), p. 62.*

Our current global situation necessitates sustainable design parameters and verification of architectural design proposals through daylighting analysis to comply with zero energy demands (refer to Chapter 2). The spatial designer's future design agendas will therefore increasingly demand ontological approaches to daylighting which consider daylight to be not only a design element providing qualitative ambiance, but also a measurable and quantifiable energy resource. This requirement for numerically verifiable daylighting design strategies calls for an altogether different engagement with, and epistemic perspective of daylight – light as measurable energy.

This research study demonstrates a gap in research about the knowledge acquisition of daylight and a lack of pedagogical research into the construction of this knowledge within spatial design. The literature review and pilot studies sought to describe current assumptions and pedagogical approaches within defined spatial design "Communities of Practice". Chapters 2 and 3 define the imbalance and consequence of designers working with qualitative daylight approaches alone. They also characterise spatial designers' limited engagement with quantitative approaches to daylighting design, confirming an urgent need to address this. It was the intention of this research study therefore to first explore, then propose methods or tools by which daylighting, being both a qualitative and quantitative element of design, could be better understood and optimised by those spatial designers working with it.

Further to these early research investigations, it was apparent that in order to advance pedagogical approaches to bridge the gap between these two ontologies, it was necessary to explore and evaluate existing methodologies for the teaching of daylight. As pilot study workshops were undertaken to investigate pedagogical methods, themes emerged that called for the recognition of a dual ontology for daylight. Few, if any, existing methodologies engaged with both ontologies for daylight or made any meaningful connections between them. The dual ontological perspective proposed in this study embraces the opposing ontologies for daylight - qualitative and quantitative - with equal value. This new methodology required alternative approaches to spatial design thinking in relation to daylighting, previously unexplored in spatial design practice or educational contexts.

For this research study I therefore chose to focus on the development of new methodologies and tools to support pedagogical practices for daylighting within spatial design. New pedagogical approaches through studio, labs and field trip workshops were proposed with the ambition to encourage spatial designers' engagement with this proposed dual ontology for daylight.

These workshops implemented tasks and corresponding methods using, "Designerly ways of knowing" (Cross, 2006), through participants developing familiar drawing, model making (physical and virtual) and iterative design processes in new, combined approaches. The research study sought to familiarise workshop participants with a set of "threshold concepts" (Cousin, 2006) developed further from the Pilot Study Workshops. Trials of these "threshold concepts" in the pilot study had revealed the particular success of the 'relational' daylighting concepts and daylighting metrics. It was observed by the focus group facilitators and me that participants talked more of holistic design agendas, considering materials, spatial volume and atmosphere when exploring these relational concepts. This demonstrated a better balance of quantitative and qualitative ontologies for daylight.

The concept thresholds were engaged with 'experientially' by workshop participants. These 'experiential' methods were derived from a synthesized list of pedagogical constructs; to 'see' (Gustina and Brandston), to 'touch' (Pallasmaa and Holl) and to 'record' daylight (Andersen and Theodorson) taking inspiration and insights from eminent designers, researchers and teachers from the domain of spatial design. It was expected that the proposed methodologies would provide guidance for daylighting curriculum within current spatial design contexts. Additionally, the research study sought to find methods that could be applied to future spatial design agendas (whether physical or virtual) through application of the methodology.

8.2 How can new pedagogical methodologies for daylight provide 'epistemic moments' for spatial design?

Conversational analysis of the workshops was undertaken within Linkoder with coding derived from the 'situated' Function – Behaviour – Structure (sFBS) Framework (Gero & Kannengiesser, 2004). Although the FBS ontology is commonly used with Linkography for analysis purposes the Linkographs constructed for this project were coded using a developed FBS ontology (situated FBS), acknowledging participants', 'situated' context, aligning with proposed daylighting competencies. Each conversation was parsed and coded in relation to the idea behind each utterance and whether it aligned with the Function, Behaviour or Structure of daylight within the task set (refer to Chapter 6).

Whilst observing the workshops it was clear that learning was taking place. Participants developed their reasoning for their design moves through actions and conversations as they carried out the tasks with consideration of the behaviour of daylight. However, when closely examining the Linkographs after the workshops, it became evident that changes in some participants' epistemology of daylight were occurring. It was possible to identify and record valuable 'epistemic moments', instances when an authentic change in the understanding of daylight was made possible. This was noted as arising when participants experienced the workshop process and created their own translational methods/approaches in relation to daylight in architectural space, developed from the proposed combined methods. As demonstrated in Chapters 6 and 7, this was clearly evident in the workshops that used model making approaches alongside the measurement of luminance contrast ratios to assess lighting contrast within a space. This was also demonstrated when participants using VE software for daylighting were able to reflect on previous field trip visits using the same case study.

These modifications within a designer's epistemological perspective were considered important as any such changes suggested increased ontological perspectives too. These modifications to conceptual understanding of daylight were recorded most commonly as increased understanding of relational concepts between light and architectural space or material behaviours. This signified a change in the value given to daylighting design by the designer, thereby opening up considerably more opportunities to engage with it.

Further, I conclude that findings from this study have determined that a broadening epistemological perspective of daylight does not necessarily demand an ‘epistemic moment’ in a workshop as such, but is more akin to a longer term ‘epistemic bridging’ between the differing ontologies for daylight, allowing a dual-ontological perspective to grow and develop as a designer’s epistemological perspectives evolve.

The literature review suggested that this increased engagement with quantitative ontologies for daylighting cannot be brought about solely by legislative demands for architectural designers to use daylighting metrics or engage better with digital tools. However, the workshops were able to align/layer and provide simultaneous translations between quantitative and qualitative visual data and the language of daylighting concepts, an approach that is currently not used in contemporary architectural pedagogy or practice with its emphasis in using detached quantitative or qualitative methods. This study determines that it is only through understanding the diverse ontological perspectives of daylight and the relationships that these have to each other and to spatial design that this issue can be revealed and addressed in architectural communities. Understanding of relational concepts in architectural daylighting is necessary - light cannot be observed as a single element, it demands recognition through its behaviour and interactions within the given space. This epistemological approach allows daylighting to be integrated into architectural design processes more holistically.

8.3 How can these methodologies benefit future spatial design and daylighting agendas?

A set of heuristics for daylighting design, conceived during the workshops played a significant role in the success of the workshops and development of appropriate threshold daylighting concepts. As workshop participants discovered methods to manipulate the light; shading in drawings, swapping out materials in physical and virtual models a heuristic language was developing alongside, providing ‘designerly translations’. These heuristics, as a list, and subsequently reinvented in a visual lexicon by some, provided guidance on practical actions to manipulate daylight, a challenging task for novice designers. The list generated was not definitive in its boundaries, rather it served as a tool, a set of illustrated beginnings to activate spatial design enquiry, "assembled to ignite the design process" (Di Mari, 2014).

Through a re-considered methodological approach, informing aligned pedagogical approaches, this research study suggests that we can come closer to the aspiration of holistic design understanding through engagement with the daylighting design throughout the whole design process. It is proposed that through applying methodologies that promote physical and digital experiential explorations as overlapping information, the disconnect between the types of information produced might be reduced. Further, by engaging with heuristic learning techniques through 'see'ing, 'touch'ing and 'record'ing light using qualitative and quantitative methods simultaneously this can be achieved with some success (refer to Chapters 6 and 7). Epistemic moments originating from epistemic artefacts such as physical models or experiences in studio or on a field trip, such as physically testing for the 'no-sky line', aid this understanding through translation of spatial design relationships and motivations. This gives new values and motivations for the analysis of quantity (lighting metrics) and quality (atmosphere) of daylight, establishing new meanings, cognitive connections and the beginnings of a shared value system for daylight within CoPs.

The results of the Pilot Study implied that the rationale behind many daylighting metrics is not clear to the spatial designer, in their use or application. This was empirically demonstrated in the pilot study Practitioner's Survey, where spatial design practitioners highlighted that 80% were unclear as to when daylighting metrics and measures could be utilised to their best advantage and many were unable to describe the daylighting metrics to demonstrate clear knowledge of the underlying concepts. The workshop methods were shown to address the understanding of metrics to some degree. As participants physically explored many of the metrics and clearly were able to draw upon this experiential memory in later workshops in the application of the daylighting metric in the same space, but realised within a different format. These threshold concepts and the methods proposed to achieve some learning of them, as outlined in the research study workshops are of course not conclusive, but do create a basis on which other metrics and those still in formulation can be built upon. It is proposed that a clear 'relational' connection between the built spatial environment and the daylighting phenomenon is all that is required to ensure the metric can be successfully demonstrated and grasped by novice spatial designers.

The methods used in the research workshops may be viewed as rather simplistic, and even archaic by some educationalists or lighting researchers involved with the development of new technologies. Other than the use of VE software and lighting measurement applications on mobile devices, no new ‘tools’ or technologies are proposed. Instead, what this research proposes is the application of new methods to approach daylighting design, derived from a strong methodological perspective that can be applied to current and future design tools and software as it develops. These methods provide insights into relational understandings between the ‘numbers’ of daylighting and the material and formal expertise of the spatial designer through exposing the effects of these interactions, between the quantitative and qualitative aspirations of daylighting design. Without this approach, daylighting metrics and their underlying concepts may become lost in the rapidly progressing field of daylighting verification and compliance, proving increasingly complex and impenetrable for the non-specialist spatial designers that dare to engage with them.

Digital daylighting software allows daylighting data to be generated seamlessly and few architectural designers have shown this to be problematic. However, clearly the translation of this information into useful project information is less successful if there is no clarity in the metrics or daylighting concepts underpinning them. As designers interact with daylighting digital software’s user interfaces, the methods and scripts for generating the resultant numerical values is hidden, and the relationships between the numerical lighting values and the spatial design decisions obscured.

Marilyne Anderson talks of a software tool her team developed and are still developing for daylighting analysis (refer to Chapter 2 for details). However, she suggests it is “premature” to hand over this tool to ‘architects’ (spatial designers) as the complexities of the issues the software needs to address to consider the “perceptual and the health aspects of daylight” are significant.

> *They [spatial designers] might get an answer or a set of numerical values from it but how would they know what this answer means? With only the answer, but without the ability to interpret it, you might take a decision that is wrong…there has to be an effort to educate…so that the underlying concepts are better understood.*
>
> *(Andersen & in Schoof, 2017), p. 28.*

Many software developers are researching solutions to create improved speeds and accuracy to encourage designers to engage better (refer to Chapter 2). However, few spatial designers have reported that the speed of calculation is problematic. Rather, it seems that this research and development of the software may be misaligned, particularly for use in educational contexts. The results of the Pilot Study Questionnaire suggest that the output data from the software would be more frequently used if it could be understood, and therefore assigned more value by designers as an important part of their design process. The hidden processes that generate the lighting data in digital software may be better understood if exposed to the user in an intermediate form, rather than concealed behind the user interface.

Additionally, the language used to define the input values and further appropriate heuristic actions for analysis of the daylighting is also loaded with technical meaning. As soon as the relatively straightforward relationships; angles of the sun to sill height and areas of window to wall are removed from sight, designers lose their understanding of how the numerical outputs are generated and the rationale behind the metric itself. In order to understand daylighting software output data fully it is crucial that the designer is given the full story, for example; what parameters were used for this calculation, what values were assumed and what does the terminology really mean in design language? This is important information, without which the designer’s understanding of these input values is limited, rendering it impossible to analyse results and revise the design appropriately to suit the holistic spatial design rationale and design priorities.

8.4 Future agendas and research opportunities

> *Light has a new prolific dimension today as a means of measurement and communication.*
>
> *(Holl, 2000), p. 14.*

This thesis therefore invites further study in the domain of spatial design pedagogy through further testing of this pedagogical approach. Additional explorations in the field of daylighting pedagogy are proposed, serving to expand further the methods and associated heuristics for designing with daylight aligning with spatial designers' 'designerly ways of knowing and thinking' (Cross, 2006), whilst ensuring both qualitative and quantitative ontological perspectives of daylight are promoted within the design process. This study implies that no single method or daylight tool can achieve these often undetermined goals in the "ill-structured" (Duffy & Jonassen, 1992) holistic, domain of spatial design. However, it is proposed that familiar design thinking using the combined methods of 'seeing', 'touching' and 'recording' light can assist engagement with daylighting threshold concepts and address the abstract notions of the "thingness"(Holl, 2000) of daylight.

By outlining this layered dual-ontological approach (see Chapter 5), using superimposed qualitative and quantitative data, spatial design tutors will be able to successfully promote connections between the perceived opposing ontologies for daylight as design students develop their own epistemologies of daylighting connecting these two strands. Further methods to achieve this symbiosis of qualitative and quantitative characteristics of daylight will serve to supplement the options available to spatial design academics or teaching practitioners. There is still a need for additional practical applications for this methodology in a field where much of spatial design curricula dictates either a quantitative *or* qualitative approach to daylighting, and textbook and pedagogical approaches are aligned to satisfy this epistemic perspective.

Although the study here was limited to application in educational contexts it is critical that these issues are also addressed in professional practice. The questionnaire provided evidence of the current context of daylighting agendas within spatial design in the UK. Although these perspectives can only be discussed in relation to local issues, some of the findings point to larger issues than can be presumed to be globally relevant. Many spatial design practitioners are limited with time. This suggests that the explorative, heuristic methods as undertaken in the pedagogical setting of the research study workshops may not be appropriate within the time constraints imposed in a design office environment. Therefore, further research could usefully consider methods to address the problematic quantitative ontological basis of available daylighting software, revised to embrace ‘designerly ways of knowing’ about daylight that designers in practice are calling for (Refer to Chapter 3).

Lighting tools and metrics are changing worldwide to suit new sustainability targets and local lighting regulations. They are increasing in their complexity and use (Mardaljevic & Christoffersen, 2016) and unfortunately will ultimately become the domain of the specialist consultant if appropriate tools cannot be found to engage with Cross’s (2006), (2011) “designerly ways of thinking and knowing” (the working methodologies) and epistemologies (how we know what we know about daylight and how this knowledge is constructed). It is at this junction that new epistemologies for daylight within spatial design become most crucial as they serve to deal with quantitative design within the evolving discipline of spatial design, or instead retreat further into limited epistemologies of atmospheric ideals.

Reversing the growing trend of directing design related to quantitative daylight measures to specialist lighting or electrical engineers (see Chapter 2) can only be achieved by a change in epistemologies and design approach. Studies suggest that any “built environment designer” could be considered as from the same discipline, yet, as ontological and epistemic values of daylight within architectural communities of practice are very different (see Chapter 2) this study suggests that every spatial designer must have a willingness to relate to the different domains within spatial design, to ensure the qualitative aspects of the architectural proposal are guarded.

This scenario invites consideration of supra-disciplinarity (see Chapter 4), allowing autonomy and specialist knowledge within specific disciplines (or communities of practice) but a sharing of this knowledge using a dual-ontological approach where overlaps permit or develop when translations take place (when solving a given problem). The spatial designer, by applying their expertise and understanding of daylighting within their community of practice, in parallel with the shared, superimposed information acts as ‘translator’ to achieve shared understanding of daylighting concepts and decision-making. This research proposes that translations are necessary to increase the strength and number of authentic connections between the design idea and the daylighting idea to deepen understanding and familiarity. I would suggest that using the proposed approach of layered qualitative and quantitative information, encouraging a dual-ontological perspective will allow this sharing of knowledge to happen.

With improving digital software, mapping and sensors on real-time devices such as phone cameras it will become easier to carry out this approach of layering of visual qualitative and quantitative information. As the design progresses from an early conceptual stage sketch data or basic 3D models (physical or virtual) or built architectural spaces can be used as a background for the superimposing of further qualitative or quantitative information. It is important that any new proposed methodology must allow the integration of new technological tools and therefore the approach proposed in this study of superimposed layering has potential to be used with a variety of tools and spatial realisations.

It is also crucial however that any new approach to designing with daylight allows for new information generated through daylighting research and relating to spatial design, be recognised and disseminated into architectural projects. Through application and integration of layers of lighting information, the opportunity for new relationships to be created between quantitative measurement in relation to qualitative scenarios is possible. For example, glare indexes, lighting levels relating to circadian stimulus or other non-visual effects of light, when viewed simultaneously with the spatial environment (through drawings, virtual environments or augmented reality), may allow the connections between these design issues to be exposed and subsequently addressed.

Within spatial design practice, the terminology necessary to engage with daylighting can produce a barrier to engagement (see ref Chapter 2 and 3). Therefore, if practising spatial designers are to engage successfully with professional daylighting design not only will the layering of visual to numerical relationships need to be revealed, but also the associated language and terminology.

Methods are needed for the translation of specialist lighting language and data into design language, through the understanding of lighting principles. This requires consideration of architectural contexts as situated or non-situated, the mode of working within the design process, the active experience of the designer and the input and output format.

An extended daylight lexicon as trialled in this research study allows textual and numeric input and output of daylighting data from any source (digital or otherwise) to be successfully constructed, translated and ultimately engaged with (see Chapter 6). Using this lexicon as a base for translations into “designerly ways of knowing” (Cross, 2006) about daylighting from the more technical, quantitative realm, it can serve to supply the novice designer with appropriate daylighting terminology and concepts. It can evolve to define and suit new ontologies of daylight demanded of future spatial or environmental scenarios or digital advances for the more experienced professional.

This study offers insights into methodologies for spatial design pedagogy that can provide transparent relationships between experiential learning, numeric reasoning and representational techniques, seeking to encourage the creation *and translation* of daylit ambiances through the overlapping of each mode with numerical digital interactions. Through the demonstration of multi-modal tools in use, this thesis proposes future collaborations to reveal understanding of qualitative and quantitative ambiance through experiential design. This application of qualitative and quantitative measures and insights may provide improved understanding of daylight’s characteristics and potential in built environment contexts. In so doing this provides a better understanding of lighting metrics and their use in application.

Significantly, this thesis proposes limitations in its scope, in that the methods explored served to address educational parameters. However, the developed dual-ontological approach in its theoretical application may prove unlimited. This methodology of practice is wide ranging and may provide a basis for further research addressing collaborative pedagogies within related fields of spatial design or provide a methodological approach for fields where conceptual notions are difficult to grasp such as building structures, acoustics, theatre lighting design and other intangible sensory applications.

> *We need to relocate light and continue this debate, as well as to question this development in order to bring us onto a more sustainable course, where interplay, between light and form is examined further.*
>
> *(Volf, 2011) p. 108.*

This thesis does not end the debate on daylighting's role within spatial design. Our current situation, with regards to daylighting design, requires immediate attention. Spatial designers are uniquely positioned to affect the daylighting strategies in their designs. Whilst the risks in undertaking this study were sizeable (a methodology or range of methods or tools may not have determined any improved pedagogical approach) the risk of continuing to exclude spatial designers in the advancement of daylighting design is far greater.

This thesis argues for a new design approach in which the invisible fundamental elements of daylighting design can become visible through "see"ing, "touch"ing and "record"ing daylight as explored in the workshops. With daylight in mind an architectural space can be truly "conceived to meet the requirements of those who inhabit it" within holistic design intent (Traverso, 2015) p. 55.

> *The ultimate problem for the profession is that of setting out the possibilities and choices in building an environment. And in that field the crisis will not be solved by technical advance alone or by picturesque images. At bottom it is a crisis of lack of understanding. Our task is to try to make that understanding more complete.*
>
> *Martin, L in (Hawkes, 2017), first printed as discussion in (Scher, 1967), p. 229.*

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APPENDIX I **Ethical Permission**

RESEARCH PERMISSION FORM 2017

Lighting Workshops as part of Light + Colour in the Built Environment

Where: [Destination]

When:

The workshops taking place each week within the Light and Colour in the Built Environment module will form part of my research (Gillian Treacy PhD candidate at UoE). This form is to ask for your permission to use the recordings I take during the workshops and any written observations and photographic images for use in future research.

What is the purpose of this research?

The aim of this research is to find tools and methods of evaluating, exploring and engaging with lighting that are useful for design students and aid learning in the subject of lighting.

What information will be recorded?

Your sketchbooks, models and site visits may be recorded for visual and verbal analysis purposes. No names will be disclosed and no images or recordings will be uploaded to any social media sites. The information recorded will not form part of your assessment or influence marking criteria.

Where will my information be stored?

Design work and verbal recordings will be stored on a private, encrypted database. Where any image is used for publication purposes the author will be notified and credited.

I consent/do not consent to being recorded and observed

Email contact for approval of publication of drawings, photographs etc in 2018:

Name:

Email:

Signature

Date

Ethics Agreement for PhD study

Sample Research Permission Form

APPENDIX II **Questionnaire**

surveyplanet

Survey for Practitioners

Thank you for agreeing to participate in this design research. Your views will be used to improve the resources available to you when designing with light. Your information is confidential.

Questionnaire – Survey for Practitioners

1 **Please select your general job description:**

- ◯ Assistant Architect
- ◯ Architect
- ◯ Interior Designer
- ◯ Lighting Designer
- ◯ Services Engineer
- ◯ Town/Urban Planner
- ◯ Other

* Choose one.

2 **Please confirm the types of design projects that you are currently involved with?***

- ☐ Commercial Office
- ☐ Educational Building
- ☐ Residential (single house)
- ☐ Residential (large scale development)
- ☐ Community or Arts Building
- ☐ Transport Building
- ☐ Commercial other (eg. retail, storage facilities, manufacturing)
- ☐ Interior Design in New Build
- ☐ Interior Design within Existing Building

* Choose all that apply.

Questionnaire – Survey for Practitioners

3 **Please select the Contract sum of your typical project:**

- ○ £0 - 500,000
- ○ £500,00-1 million
- ○ £1-5 million
- ○ £5-10 million
- ○ £10 million +

* Choose one.

4 **In which area of the world are most of your projects located?**

- ☐ Local within 60 miles
- ☐ UK
- ☐ Europe
- ☐ Americas
- ☐ Asia
- ☐ Worldwide

* Choose between 1 and 3.

Questionnaire – Survey for Practitioners

5 **Please confirm your level of expertise as a designer:**

- Less than a year in practice
- 1-5 years in practice
- 5-10 years in practice
- 10+ years in practice

* Choose one.

6 **Please summarise your experience of daylighting design from your educational background eg. lectures, physical model studies etc**

Questionnaire – Survey for Practitioners

7 **Have you used any techniques or knowledge gained about daylighting during your education in practice?**

- Never
- Occasionally
- Frequently
- Which techniques / Knowledge / tools?

* Choose one.

8 **Have you attended any lighting CPDs while in practice?**

- Yes
- No

* Choose one.

Questionnaire – Survey for Practitioners

9 **Were any of the CPDs useful for the work your design practice are engaged in?**

- ◯ Yes
- ◯ No
- ◯ Why?

* Choose one.

10 **Do you consider daylight important for your buildings?**

- ◯ Yes
- ◯ No
- ◯ Sometimes

* Choose one.

11 **Do you design your buildings or interior spaces with daylight in mind?**

- ◯ Yes
- ◯ No
- ◯ Sometimes

* Choose one.

Questionnaire – Survey for Practitioners

12 **Have you ever carried out daylight evaluations? e.g. How much daylight you will receive into your spaces?**

- ◯ Yes, using environmental computer software
- ◯ Yes, using our CAD software
- ◯ Yes, using sketching and hand calcs/rules of thumb
- ◯ Yes, using physical models
- ◯ No
- ◯ No, we work with or employ a specialist for this

* Choose one.

13 **At what point in your design process did you carry out these evaluations?**

- ☐ Concept stage / site analysis
- ☐ Initial plans / sections / 3D forms / Concept formation
- ☐ Presentation of Proposals
- ☐ Plans / sections / 3D forms for Planning Application
- ☐ BREAM Accreditation
- ☐ Construction Drawings
- ☐ Building Warrant / Building Control Application
- ☐ Detail Drawings
- ☐ Post-occupancy

* Choose between 1 and 9.

Questionnaire – Survey for Practitioners

14 Have you ever carried out sunlight evaluations? e.g. How much sunlight you will receive into your spaces?

- ◯ Yes, using environmental computer software
- ◯ Yes, using our office CAD software
- ◯ Yes, using sketching and hand calcs
- ◯ Yes, using physical models
- ◯ No
- ◯ No, we employ a specialist for this

* Choose one.

15 At what point in your design process did you carry out these evaluations?

- ☐ Concept stage / site analysis
- ☐ Initial plans / sections / 3D forms / Concept formation
- ☐ Presentation of Proposals
- ☐ Plans / sections / 3D forms for Planning Application
- ☐ BREAM Accreditation
- ☐ Construction Drawings
- ☐ Building Warrant / Building Control Application
- ☐ Detail Drawings
- ☐ Post-occupancy

* Choose between 1 and 9.

Questionnaire – Survey for Practitioners

16 **Did you refer to any source of information for these evaluations? e.g. BREEAM guidance notes, CIBSE Lighting Guide**

Questionnaire – Survey for Practitioners

17 Without referring to any other source of information, have you heard of any of these lighting metrics or units of measurement?

- [ ] Luminance
- [ ] Illuminance
- [ ] Daylight Factor
- [ ] Useful Daylight Illuminance
- [ ] Daylight Autonomy
- [ ] Rights of Light - Waldram diagrams
- [ ] Circadian Stimulus
- [ ] CBDM
- [ ] Please describe any terms you have selected above and note why they may of use when designing spaces

* Choose between 1 and 8.

Questionnaire – Survey for Practitioners

18 **Have you used any of these lighting metrics or units of measurement in your design proposals?**

- [ ] Luminance
- [ ] Illuminance
- [ ] Daylight Factor
- [ ] Useful Daylight Illuminance
- [ ] Daylight Autonomy
- [ ] Azimuth angle
- [ ] Rights of Light - Waldram diagrams
- [ ] None of the above

* Choose between 1 and 8.

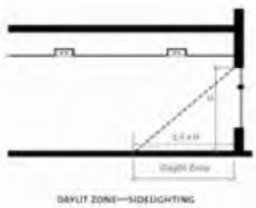
Questionnaire – Survey for Practitioners

19 Which design aspects did you use this tool for?

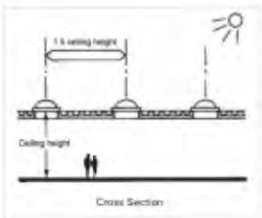
- [ ] Site planning
- [ ] Building Orientation
- [ ] Visual Assessments
- [ ] Communication with clients and/or design team
- [ ] Shading controls
- [ ] Location/shape/size of windows or skylights
- [ ] Select material surfaces
- [ ] Atria design
- [ ] Other

* Choose between 1 and 8.

20 Have you ever used these rules-of-thumb and, if so, at what point in the design process?

- [ ] 

Rule-of-thumb no. 1

- [ ] 

Rule-of-thumb no. 2

Questionnaire – Survey for Practitioners

21 **Have you ever worked with a specialist / consultant to help design the lighting for your project?**

- ◯ Yes, almost always
- ◯ Yes, occasionally
- ◯ Yes, but for artificial lighting only
- ◯ No

* Choose one.

22 **Did this specialist / consultant advice you on lighting evaluations e.g. Lux levels, daylight measurements?**

- ◯ Yes, I used their expertise fully
- ◯ Yes, I took some of their advice
- ◯ No

* Choose one.

Questionnaire – Survey for Practitioners

23 **Without reference to any other source, using a few lines of text, can you describe the daylighting of this space? You might choose to consider how high or low the light levels are and the quality of the lit ambiance you would expect?**

24 **Would you say good quality daylighting adds design value (with 0 of little value and 10 as exceptional value)?**

0 1 2 3 4 5 6 7 8 9 10

* Choose one.

Questionnaire – Survey for Practitioners

25 **Which tools, CAD systems and analysis software do you use frequently for your projects?**

- [ ] AutoCad
- [ ] Rhino
- [ ] Google Earth
- [ ] IES VE
- [ ] Hand drawings
- [ ] Gaisma
- [ ] Microstation
- [ ] ArchiCad
- [ ] Light-up Analytics
- [ ] Radiance
- [ ] Physical modelling
- [ ] Vectorworks
- [ ] Sketch-up
- [ ] Ecotect
- [ ] Photoshop
- [ ] Suncalc

* Choose between 1 and 5.

Questionnaire – Survey for Practitioners

26 Which barriers to daylighting do you mostly encounter?

- [ ] Aesthetic reasons
- [ ] Costs for glazing/glazing systems
- [ ] Payback time too long for cost savings
- [ ] Artificial lighting too easy to add to a project
- [ ] Uncertainty in my design decisions
- [ ] No time to consider the daylighting fully
- [ ] Not being sure when there will be enough or too much light
- [ ] Concerns with glare
- [ ] Client or other design team memebers do not see it as a priority
- [ ] Unsure which analysis tool to use at each stage of my design to assess the daylighting
- [ ] Daylighting data from software or specialists is confusing
- [ ] Daylighting guidance notes are confusing
- [ ] None

* Choose between 1 and 12.

27 Do you feel resources prescribing important principles of designing with daylight are easily available to practitioners?

- ○ No
- ○ Yes, but not many
- ○ Yes, plenty

* Choose one.

Questionnaire – Survey for Practitioners

28 **If you feel new resources are necessary what form might they take?**

- ◯ Mobile apps
- ◯ Easy to use software
- ◯ Software that allows plug-ins to existing CAD systems
- ◯ Design mag on-line monthly updates on new developments
- ◯ Rules of Thumb Reference Book
- ◯ City plan with sunpath/building height relationships using augmented reality
- ◯ Local space for analysis of physical models
- ◯ CPD on daylighting principles
- ◯ CPD or guide on translating lighting drawings/analysis results
- ◯ Case studies available on-line
- ◯ Other

* Choose one.

29 **Would you be able to predict the location of the sun on a given day at a given time in a specific location and understand the shadowing of adjacent buildings?**

- ◯ Yes, definitely
- ◯ Not sure
- ◯ No

* Choose one.

Questionnaire – Survey for Practitioners

30 **If you are able to do this, how and what tools would you use to work this out?**

Questionnaire – Survey for Practitioners

31 **Please select up to 8 design goals from the following list that are at the top of your agenda for lighting**

- [ ] Provide sufficient daylight to perform tasks
- [ ] Avoid under-lit areas by distributing ambient light throughout the space
- [ ] Control glare
- [ ] Save energy by maximising the time when electric lights can be switched off
- [ ] Provide sufficient light to promote circadian stimulation
- [ ] Provide views to the outside
- [ ] Solar heat gain
- [ ] Create successful visuals that show the lighting of the space
- [ ] Knowing if glazed areas can be reduced to reduce costs yet still meet daylighting criteria
- [ ] Occupants are aware of the time of day and weather outside to promote well-being
- [ ] Knowing what types of glazing are best to use
- [ ] Integrating daylight with electric light
- [ ] Use of lighting controls for energy savings
- [ ] A good Daylight Factor
- [ ] Checks for overshadowing caused by neighbouring building
- [ ] Showing good Daylight Autonomy for your design proposal
- [ ] Accurate daylighting simulations to predict the daylighting in the space

* Choose between 1 and 8.

Questionnaire – Survey for Practitioners

surveyplanet

Thank you for taking part in this survey. if you would like feedback on the results please include your email. Your answers remain confidential and will be used as part of an anonymous report within a PhD and journal.

Questionnaire – Survey for Practitioners

APPENDIX III **Chapter 3: Text Reviews**

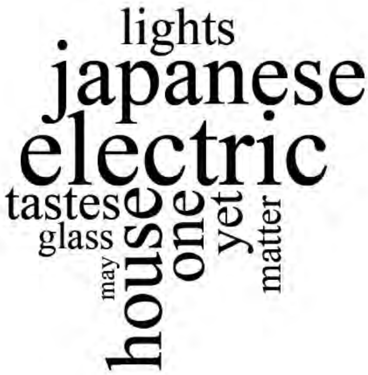
A

B

C

D

E



F

Architecture Texts – Word Trees A-F

A

B

C

D

Interior Design Texts – Word Trees A-D

A

B

C

D

E

F

Lighting and Environmental Design Texts – Word Trees

A

B

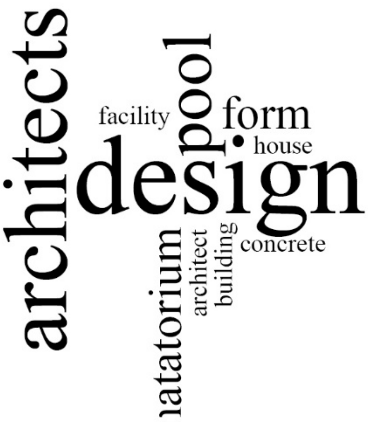
C

D

E

Lighting and Environmental Design Texts – Word Trees

A



B

C

D

E

Figure 1 - Spatial Design Magazines – Word Trees A-E

APPENDIX IV **Workshop Planning – Methods**

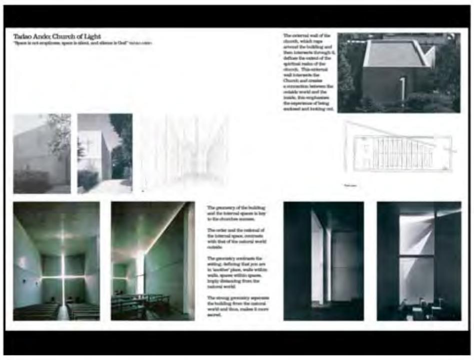
		Pilot Group A (Interiors)	Pilot Group B (Architecture)
Pilot Workshop Set 1	'Experiencing Interiors Sketchbook Project'	- Intro presentation - Case study based - Drawings (+ pantone) - Presentation on modelling solar path - Model: intro presentation to lighting measurements and terminology - Focus group for participant feedback	
Pilot Workshop Set 2	'Sustainable Daylight Field Study'		- Presentation on DF, no sky line, measuring illuminance - Nomen workshop tasks - Talk from Client - Tasks in-situ: > Drawing > Physcially define 'no-sky line' > Average DF using hand calc > Measure point DF using EdenApp
Pilot Workshop Set 3	'Sustainable Daylight VE Study'		- Short intro to software in lecture theatre - In lab imported 3D model - Tested sunpath > DF% and absolute illuminance values - Change the model to see the changed results and 'post-it'

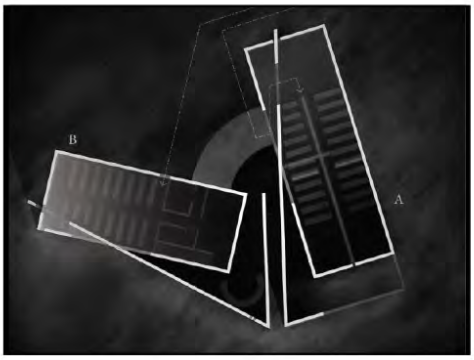
Pilot Research Workshop matrix with participant groups and tasks

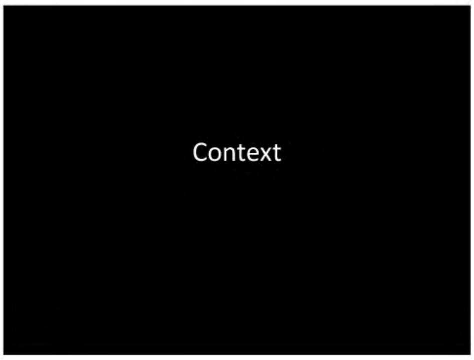
	Workshop Group A (Interiors)	**Workshop Group B** (Architecture)	**Workshop Group C** (Interiors)
Workshop 1 Describe	- Describe visual - Re-describe visual (in group) - Hand draw visual - Measure visual with Photolux - Start Visual Lexicon		- Describe visual - Re-describe visual (in group) - Hand draw visual - Measure visual with Photolux - Start Visual Lexicon
Workshop 2 Field Visit	- Presentation by Client - Hand drawing of space - Measure absolute values (no skyline) - DF hand calculation - DF Eden App - Photolux contrast measure	- Presentation by Client - Hand drawing of space - Measure absolute values (no skyline) - DF hand calculation - DF Eden App - Photolux contrast measure	- Presentation by Client - Hand drawing of space - Measure absolute values (no skyline) - DF hand calculation - DF Eden App - Photolux contrast measure
Workshop 3 Create Model: Studio	- Make model from previous drawing (given by other group) - Set up sun path - Using physical model and location to test sunpath and create matching interior effect - Continue Visual Lexicon		- Make model from photograph - set up sunpath - using physical model and location to test sunpath and create matching interior effect - Continue Visual Lexicon
Workshop 4 Model: Studio	- Manipulate physical models to comply - Measure and record DF, luminance contrast - Re-draw from model or photographs - Continue Visual Lexicon		- Manipulate physical models to comply - Measure and record DF, luminance contrast - Re-draw from model or photographs - Continue Visual Lexicon
Workshop 5 Model: VE	- Import 'field visit' model from SketchUp - Measure DF (Flucs DL) - Test sunlight (suncast) paterning - Compare with visit - Re-model to suit given DF		
Workshop 6 Visual Lexicon	- Re-describe lighting 'threshold concepts', haptic heuristics and/or daylight terminology		- Re-describe lighting 'threshold concepts', haptic heuristics and/or daylight terminology
Workshop 7 Focus Group	- Reflections on workshops - Review of outputs		- Reflections on lexicons - Re-describe image from Workshop 1 'Describe'
Workshop 8 Feedback		Completion of an on-line questionnaire	

Main Research Workshop matrix with participant groups and tasks

APPENDIX V **Chapter 5: Pilot Study**



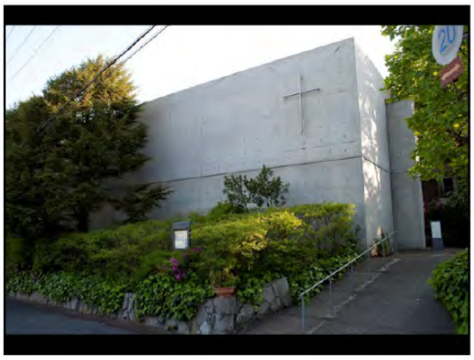


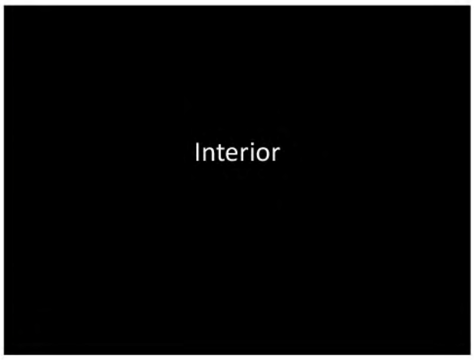


Pilot Study Workshop Set 1 Presentation:

Church of Light, Osaka, Japan (Ando 1999)





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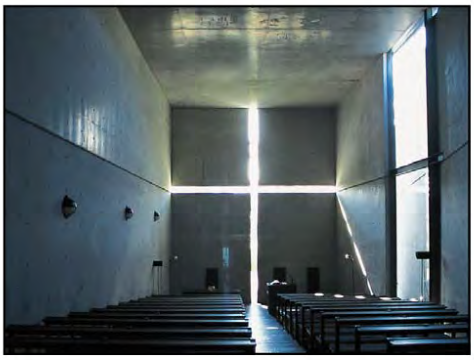

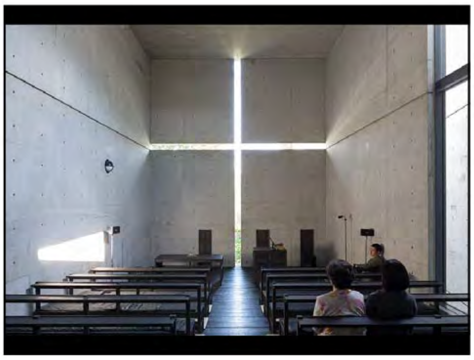

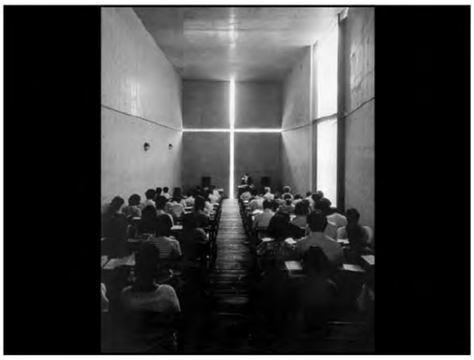

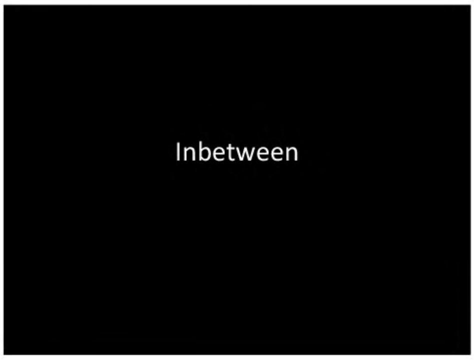

Pilot Study Workshop Set 1 Presentation:

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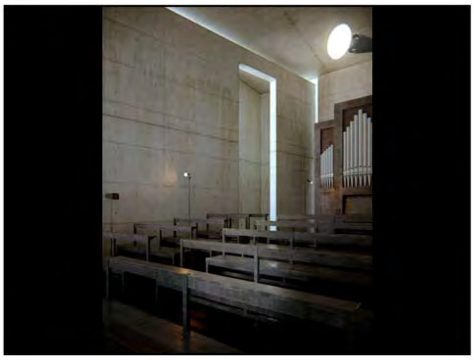

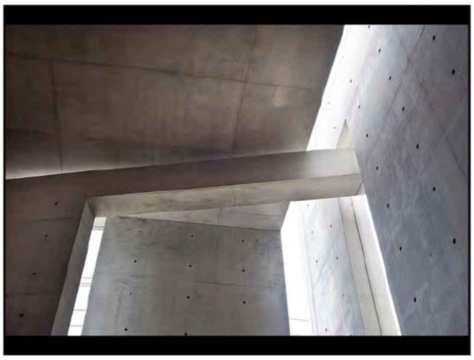

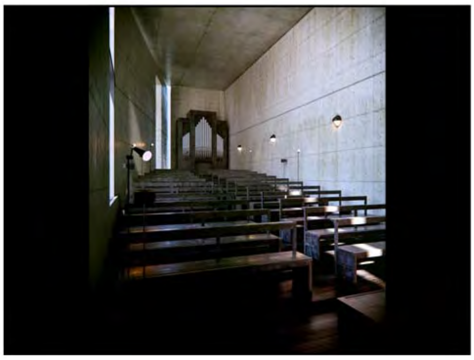

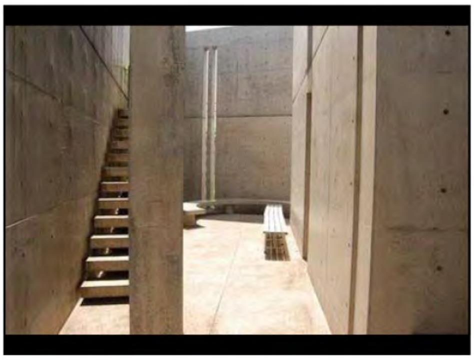

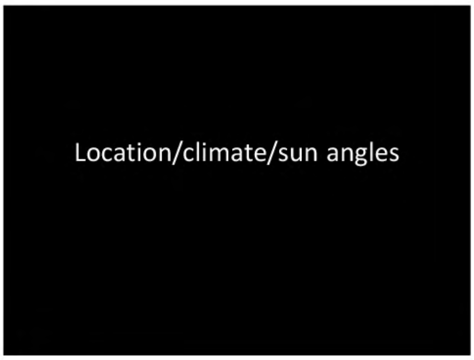

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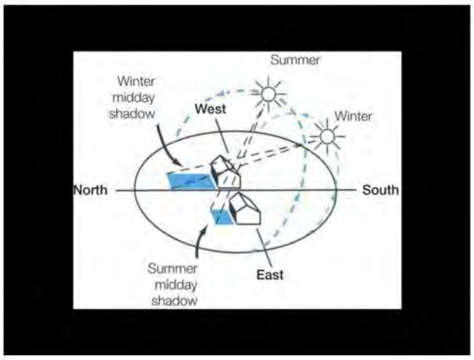
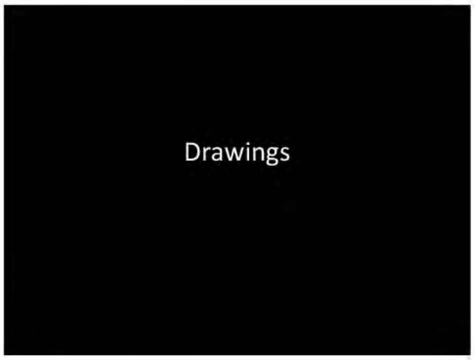
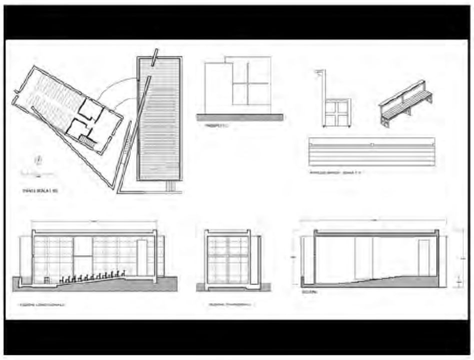
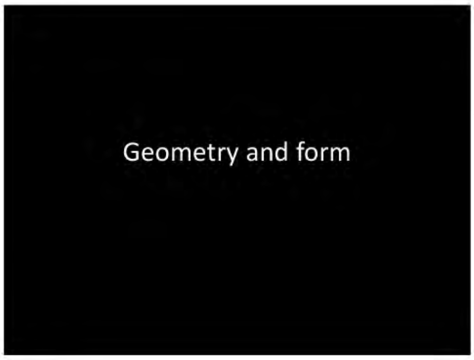
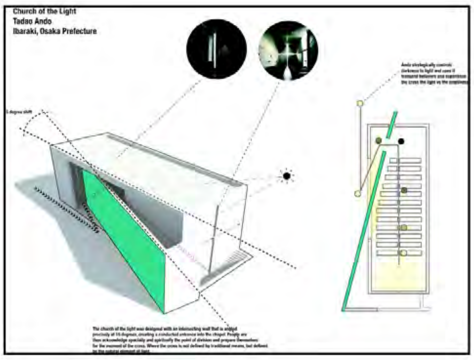
Church of Light, Osaka, Japan (Ando 1999)











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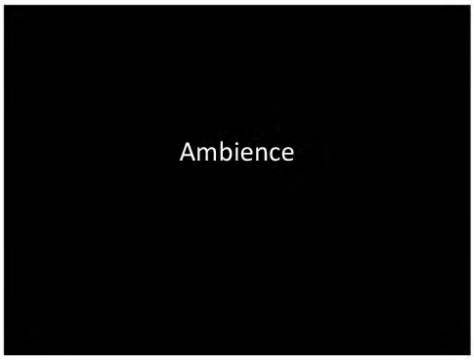
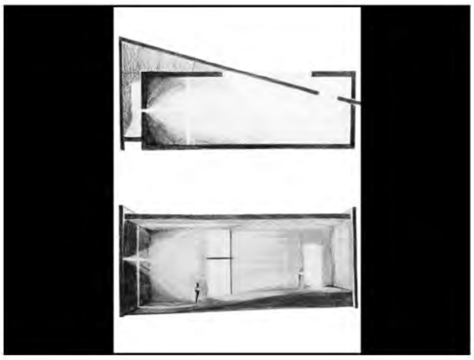
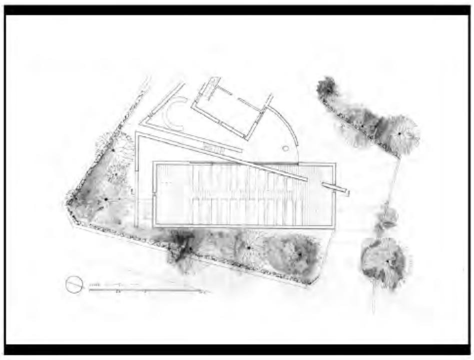
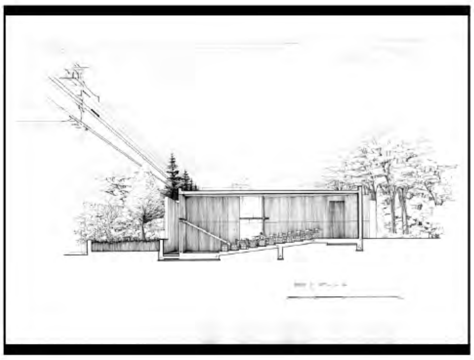
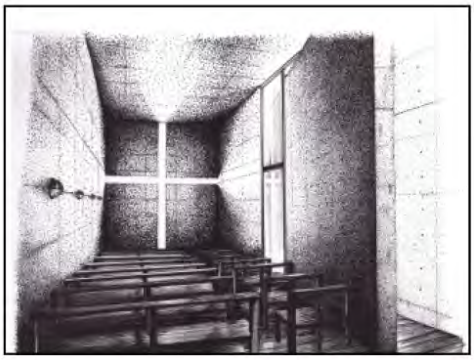
Church of Light, Osaka, Japan (Ando 1999)

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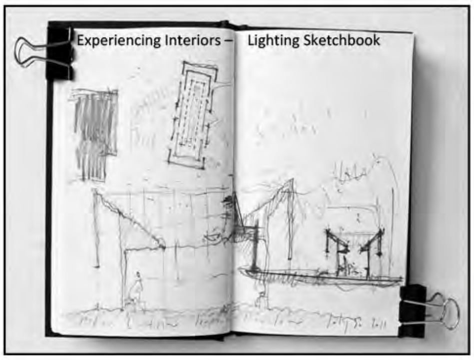
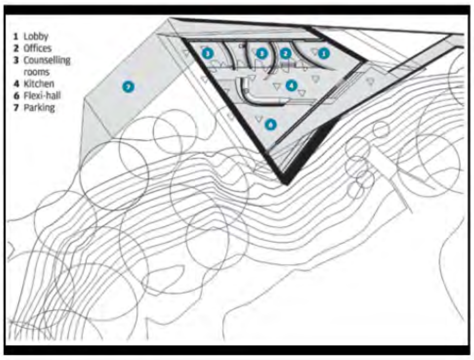
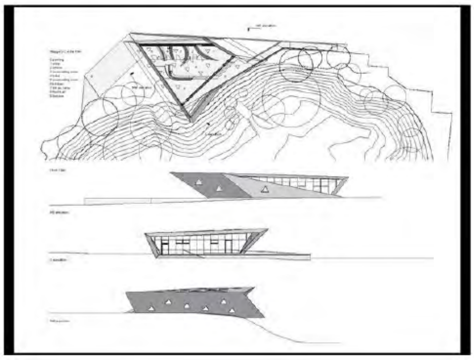
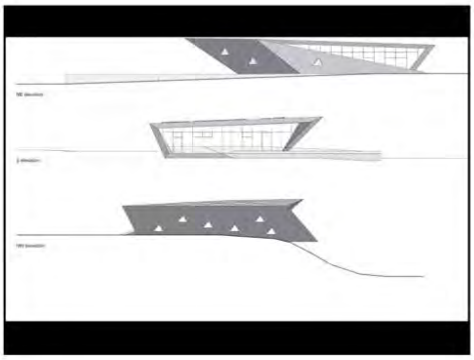
Church of Light, Osaka, Japan (Ando 1999)



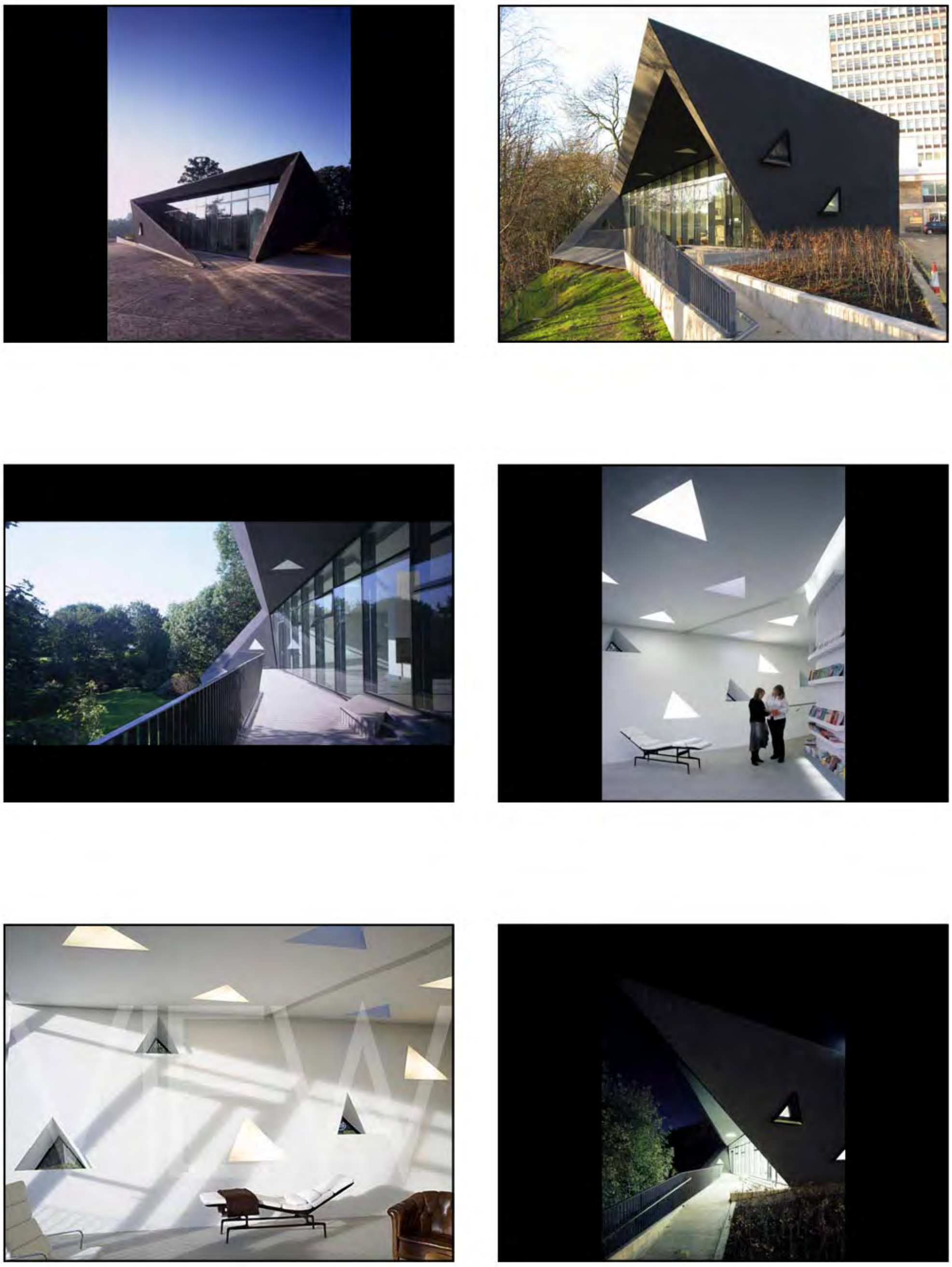






Pilot Study Workshop Set 1 Presentation:

Maggie's Centre Fife, Kirkcauldy, Scotland (Zaha Hadid 2006)



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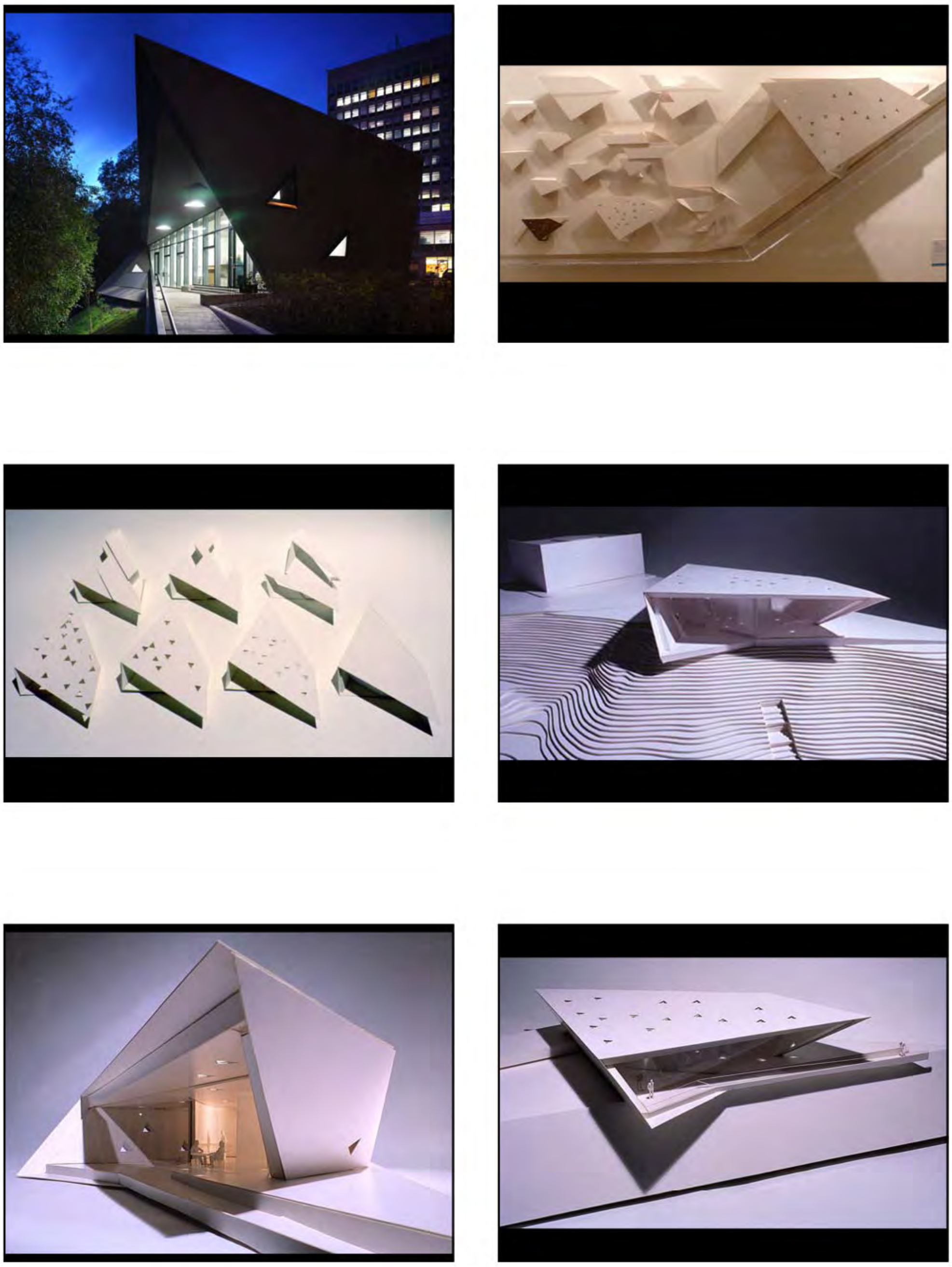
Maggie's Centre Fife, Kirkcauldy, Scotland (Zaha Hadid 2006)



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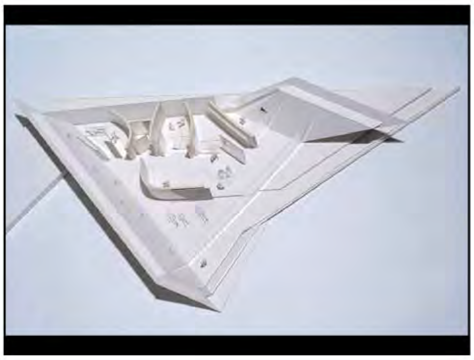
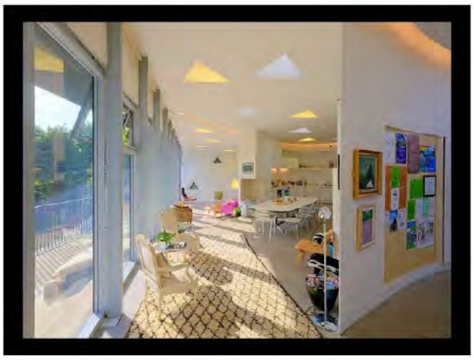
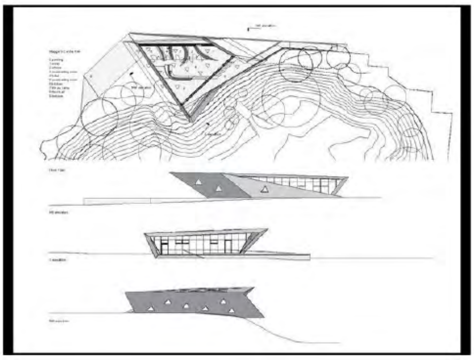
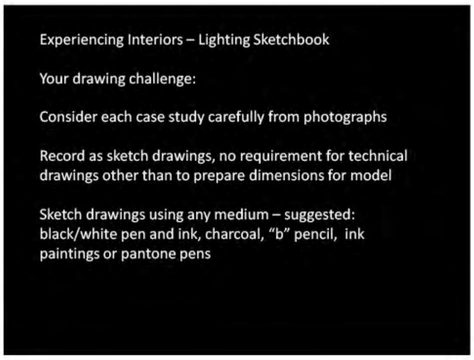


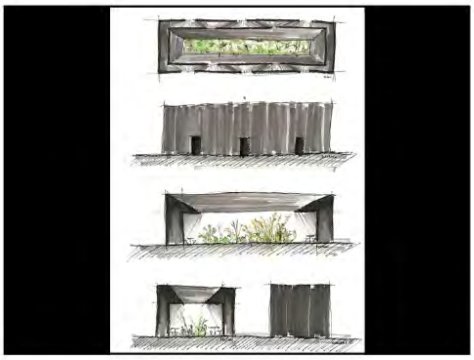




Pilot Study Workshop Set 1 Presentation:

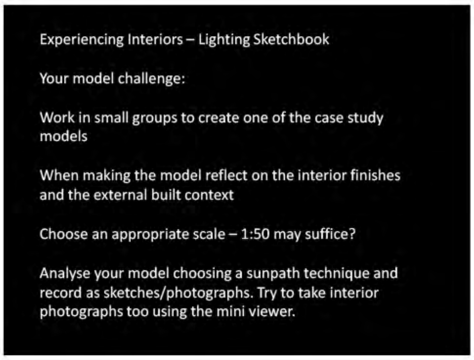
Maggie's Centre Fife, Kirkcauldy, Scotland (Zaha Hadid 2006)

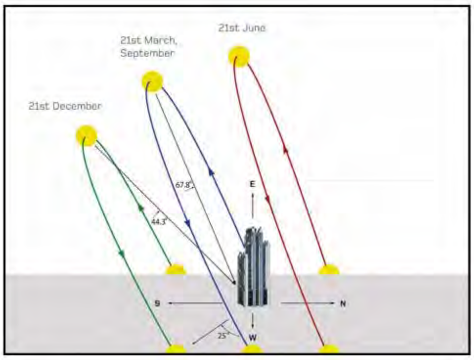


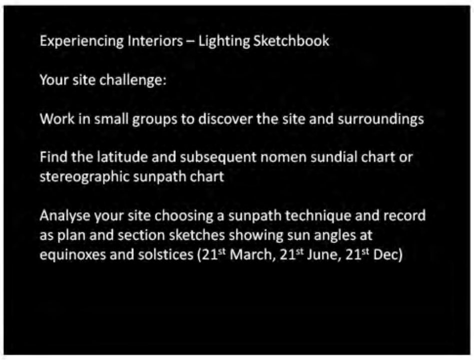


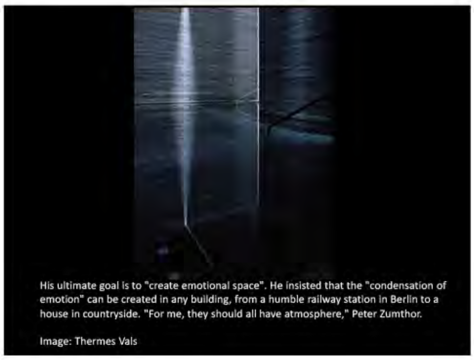
Pilot Study Workshop Set 1 Presentation:

Serpentine Pavilion, London, England (Zumthor 2011)



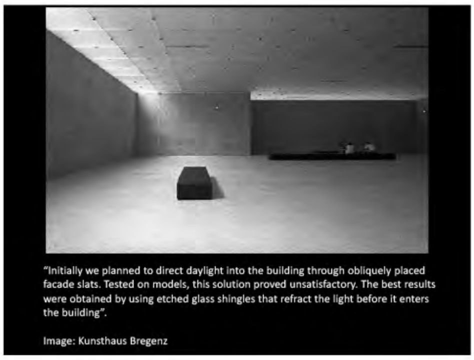






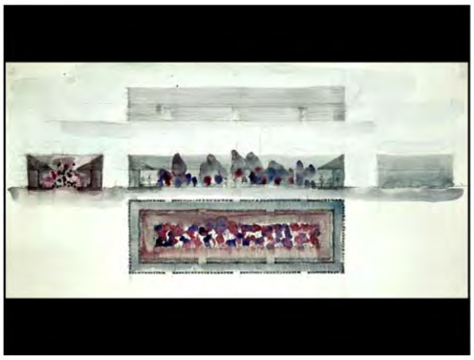
Pilot Study Workshop Set 1 Presentation:

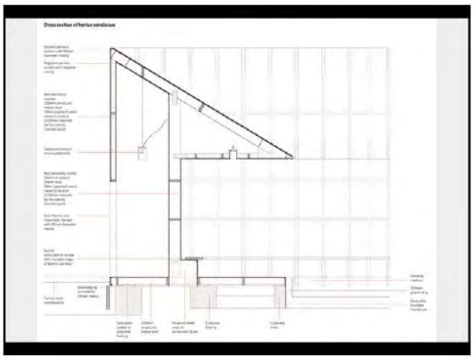
Serpentine Pavilion, London, England (Zumthor 2011)

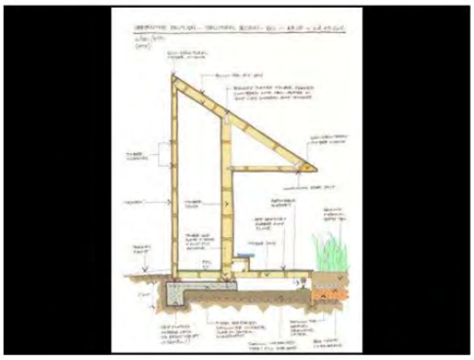


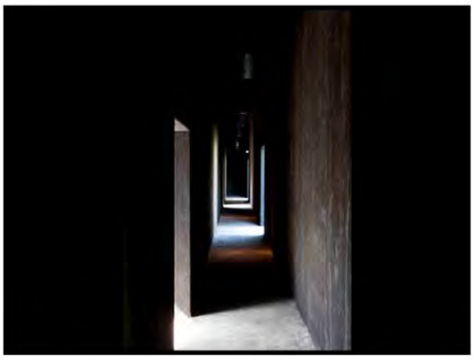
Pilot Study Workshop Set 1 Presentation:

Serpentine Pavilion, London, England (Zumthor 2011)



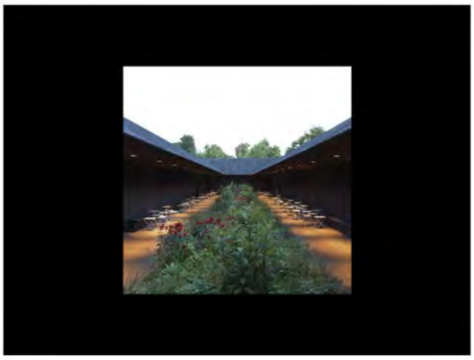


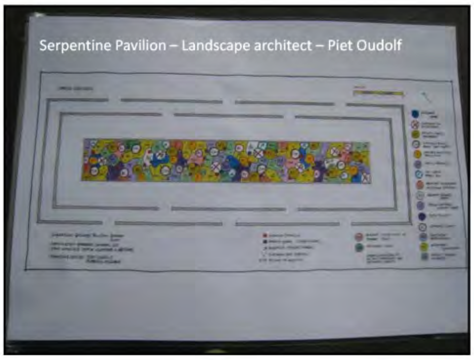


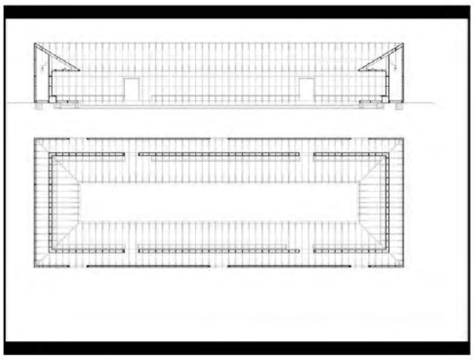


Pilot Study Workshop Set 1 Presentation:

Serpentine Pavilion, London, England (Zumthor 2011)

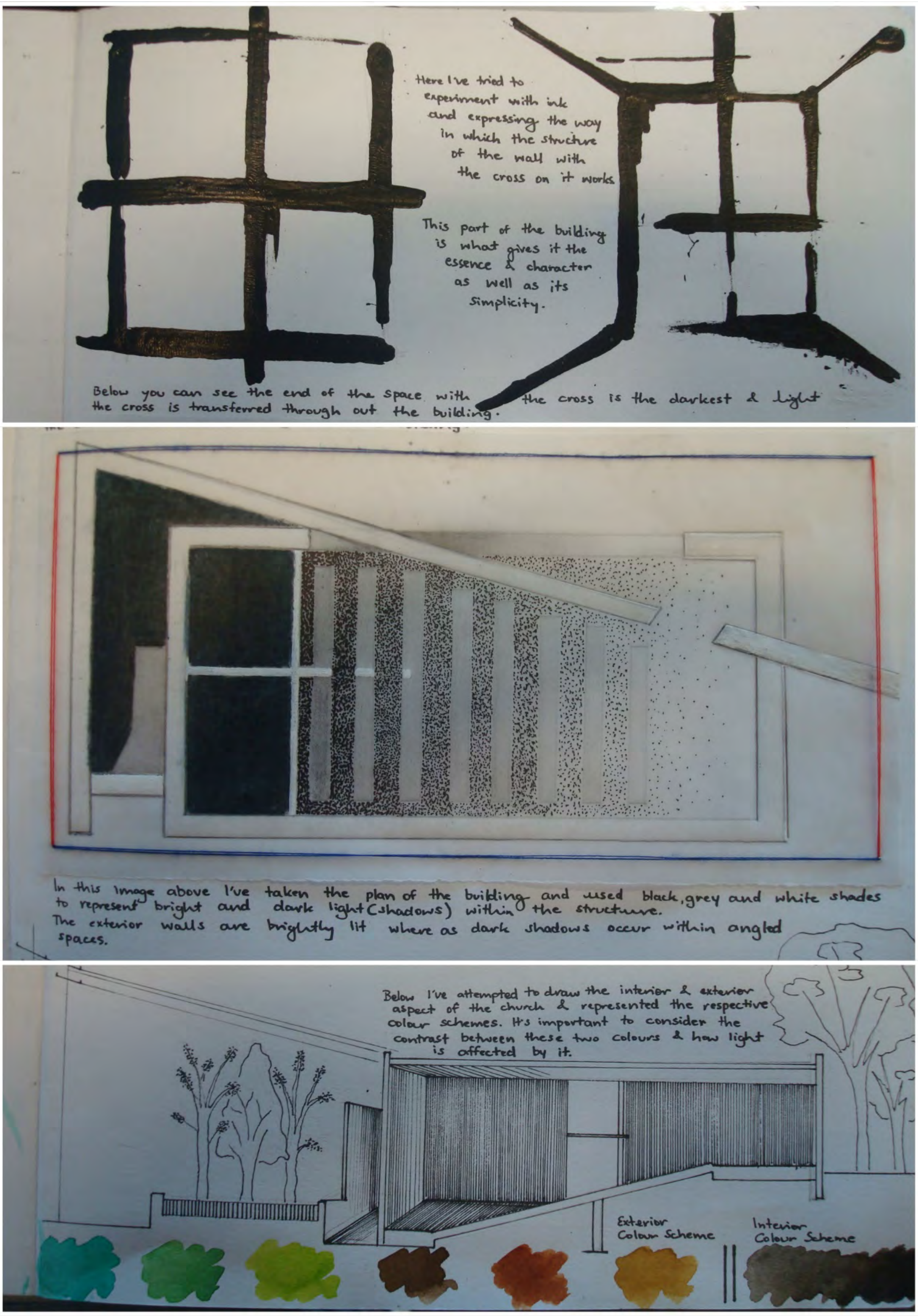






Pilot Study Workshop Set 1 Presentation:

Serpentine Pavilion, London, England (Zumthor 2011)



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Pilot Study Workshop Set 1 Participant Results:

Church of Light

A

Pilot Study Workshop Set 1 Participant Results:

Church of Light

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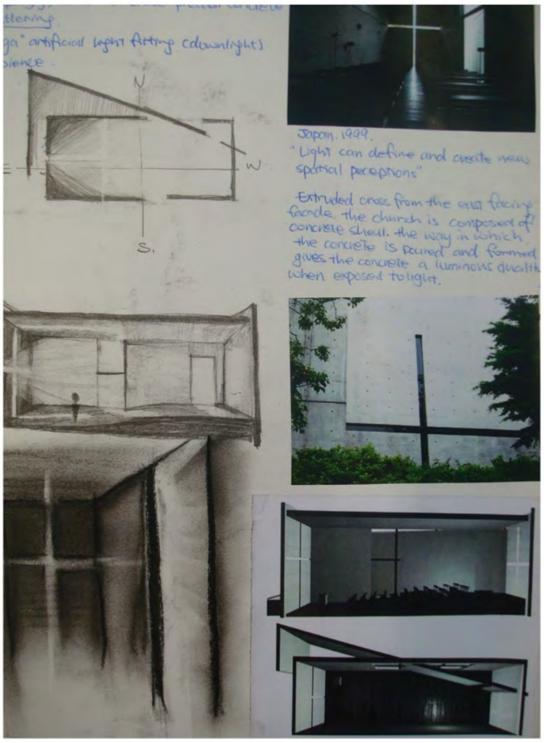

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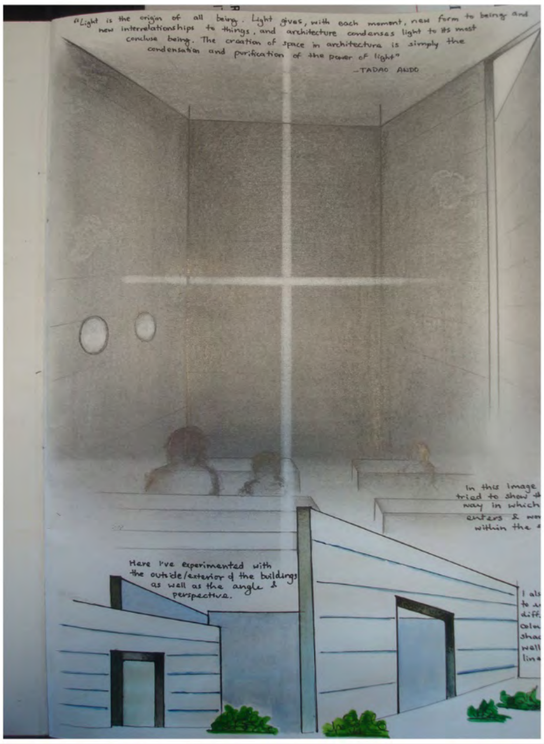

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Pilot Study Workshop Set 1 Participant Results:

Church of Light

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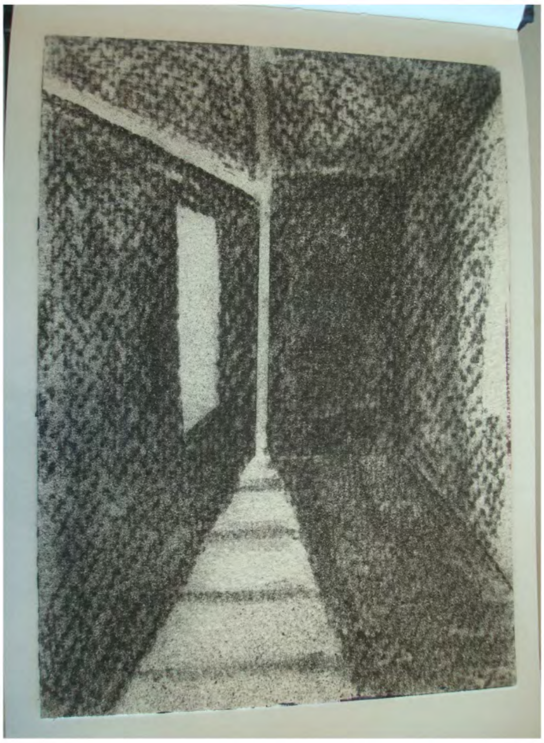

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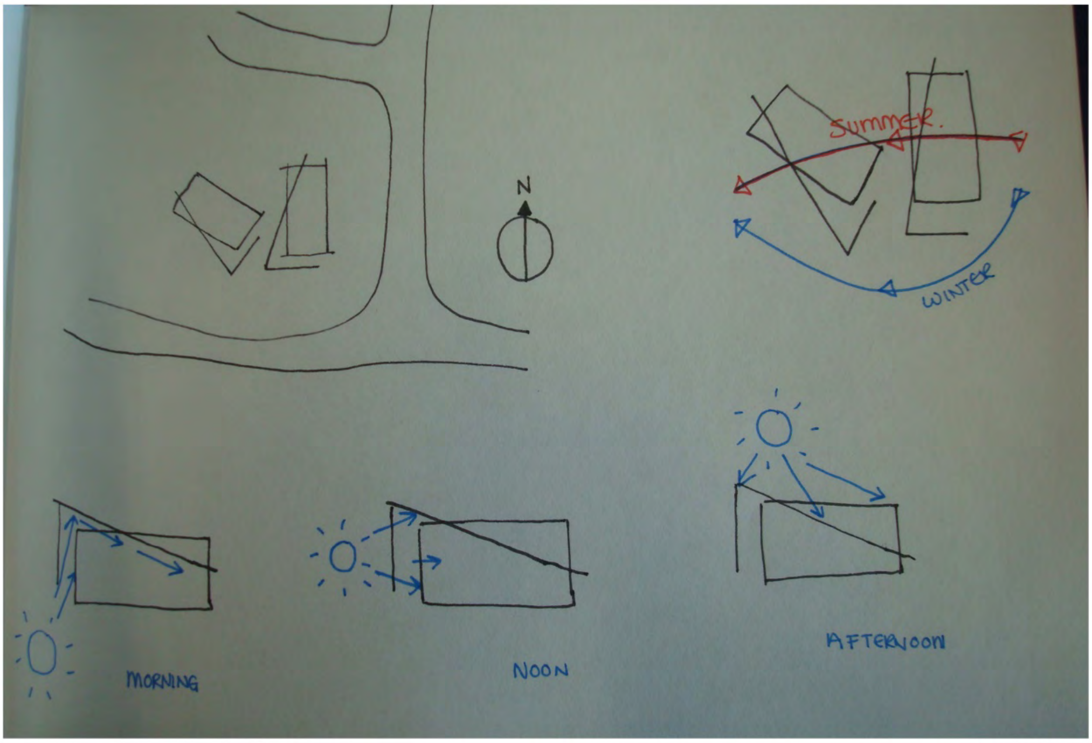
Pilot Study Workshop Set 1 Participant Results:

Church of Light



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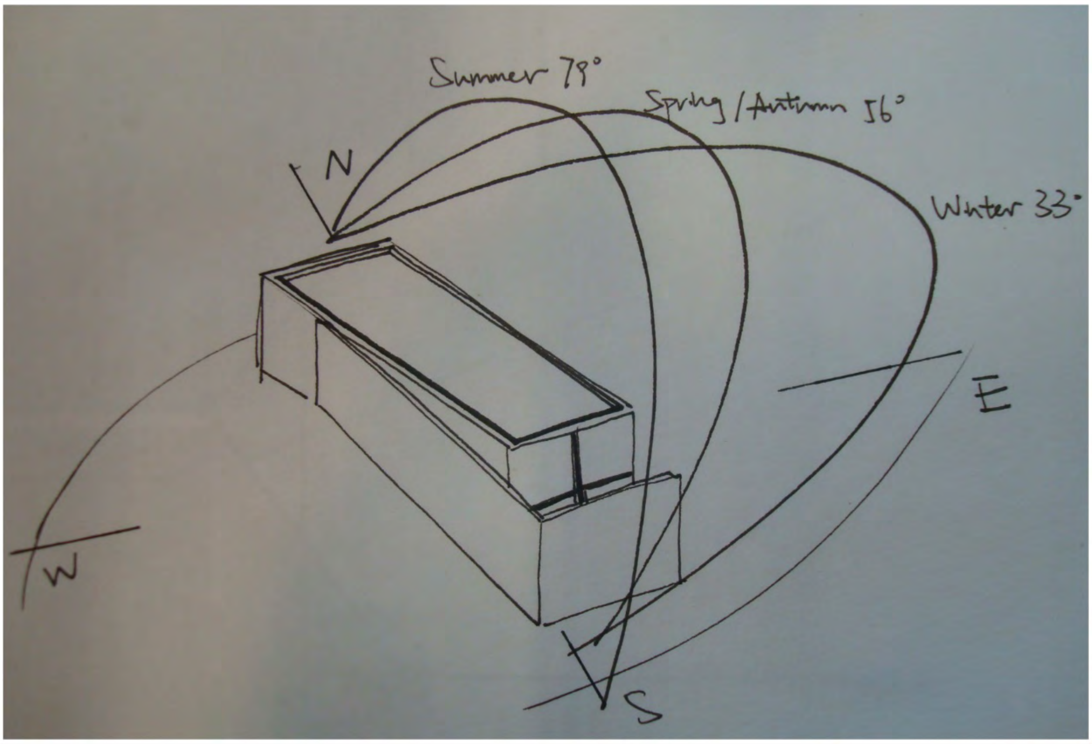

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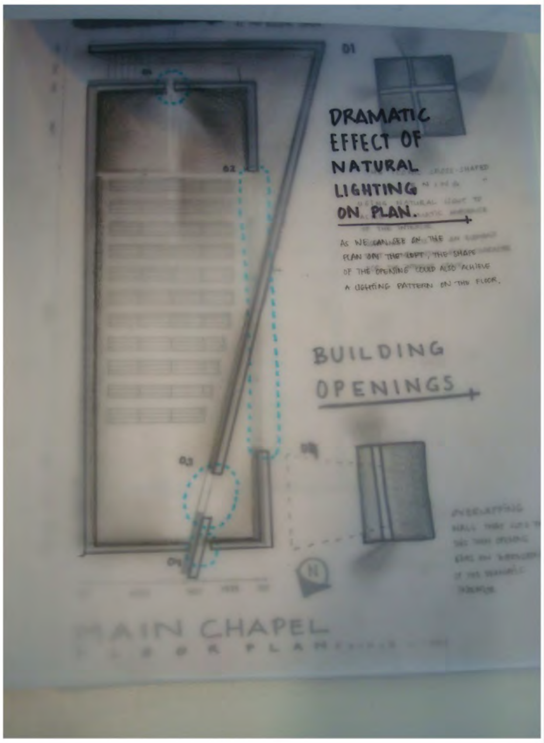
Pilot Study Workshop Set 1 Participant Results:

Church of Light



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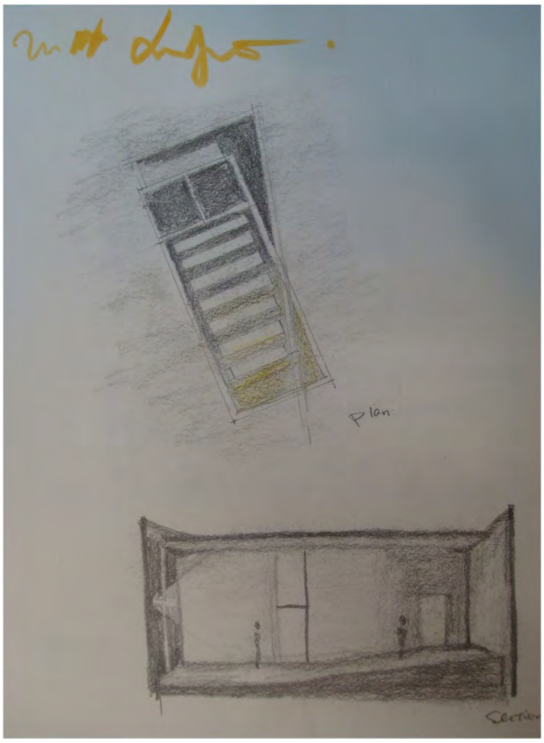

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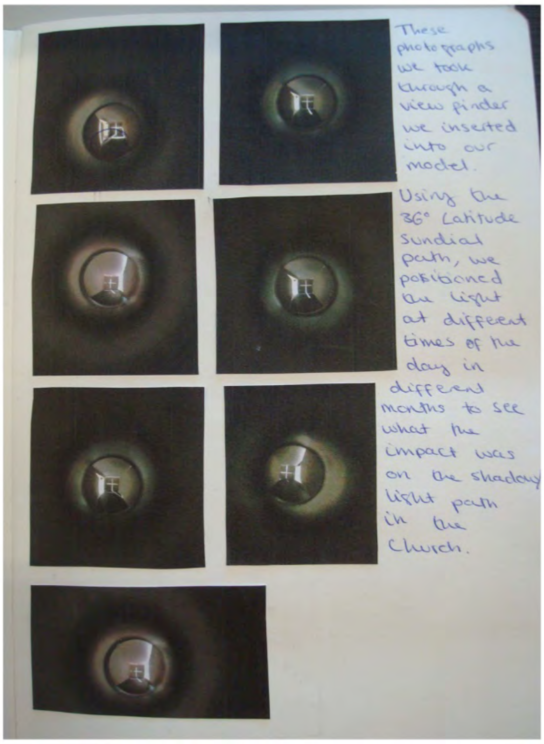

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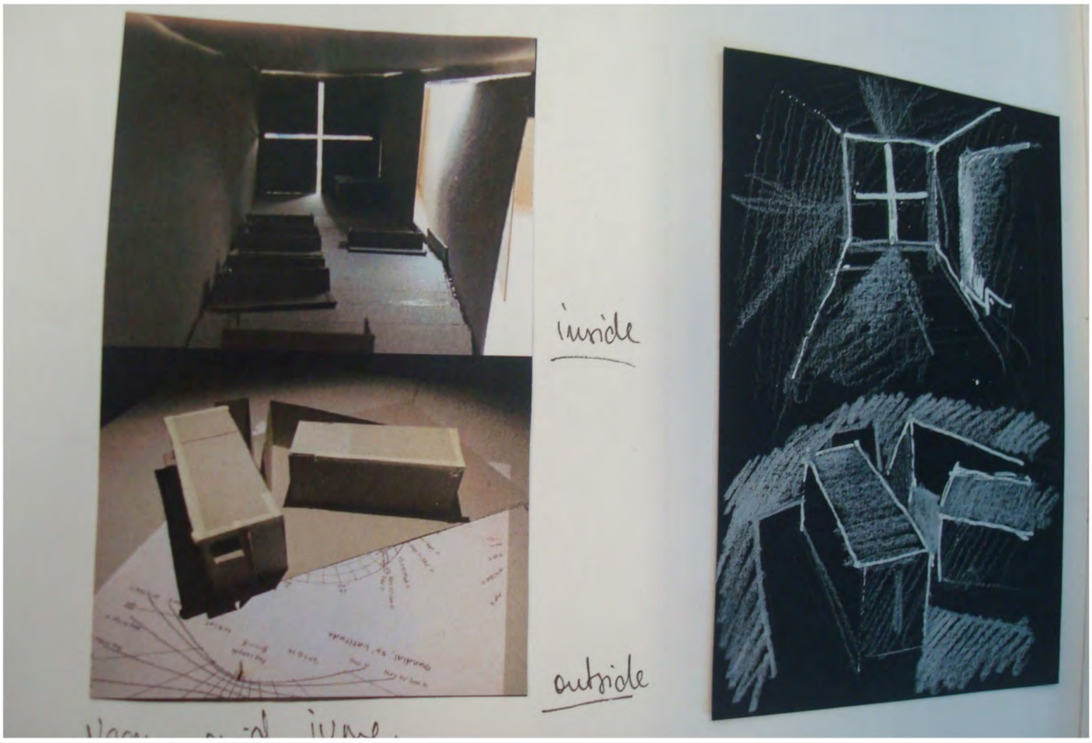
Pilot Study Workshop Set 1 Participant Results:

Church of Light



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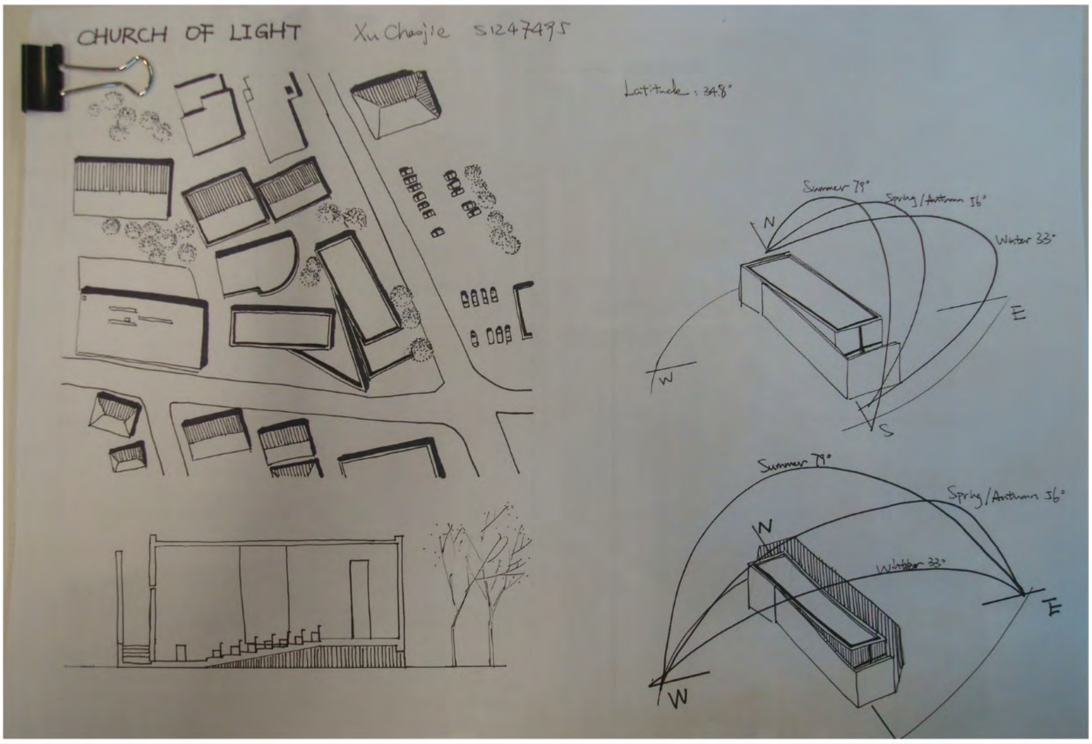

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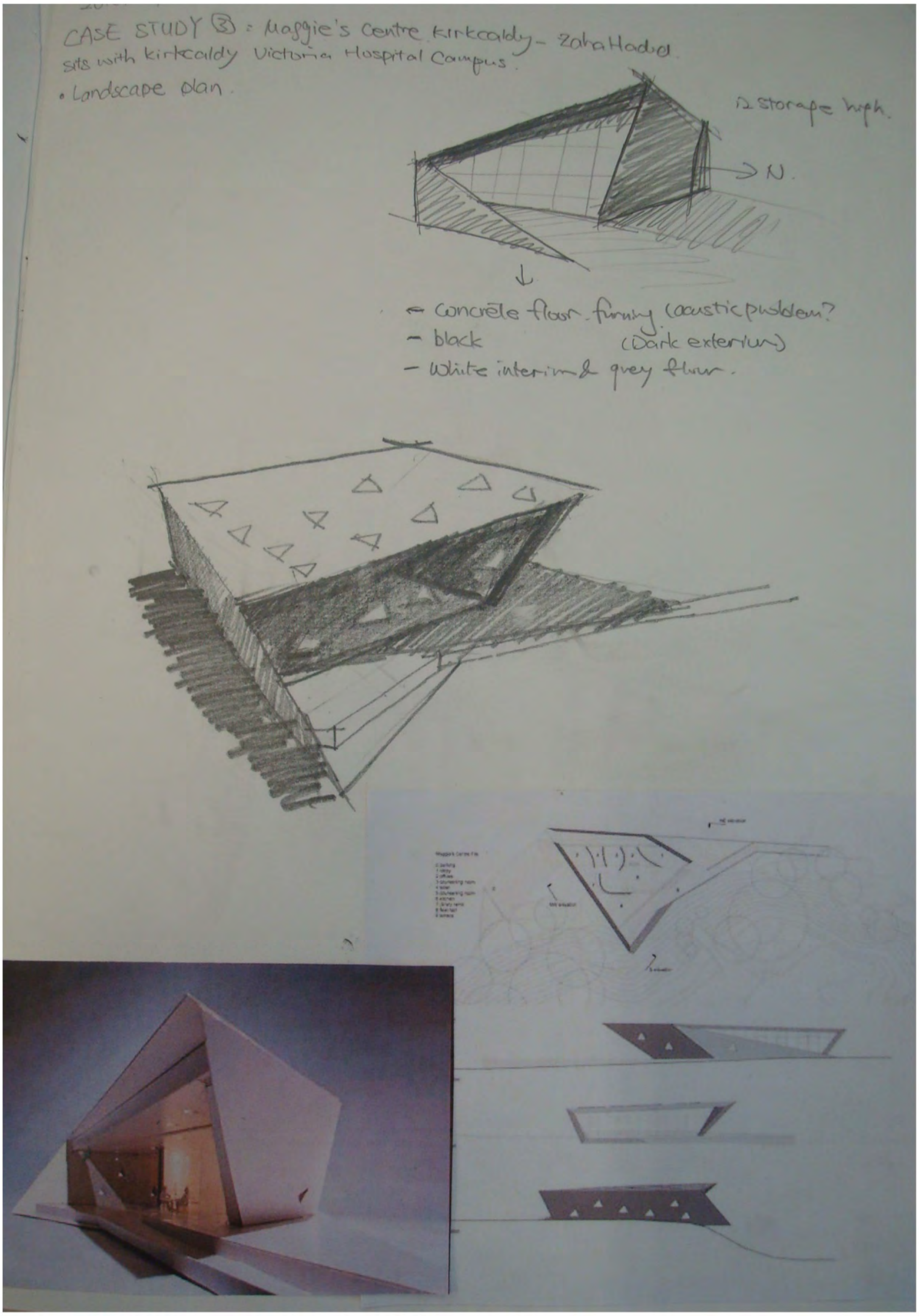
Pilot Study Workshop Set 1 Participant Results:

Church of Light



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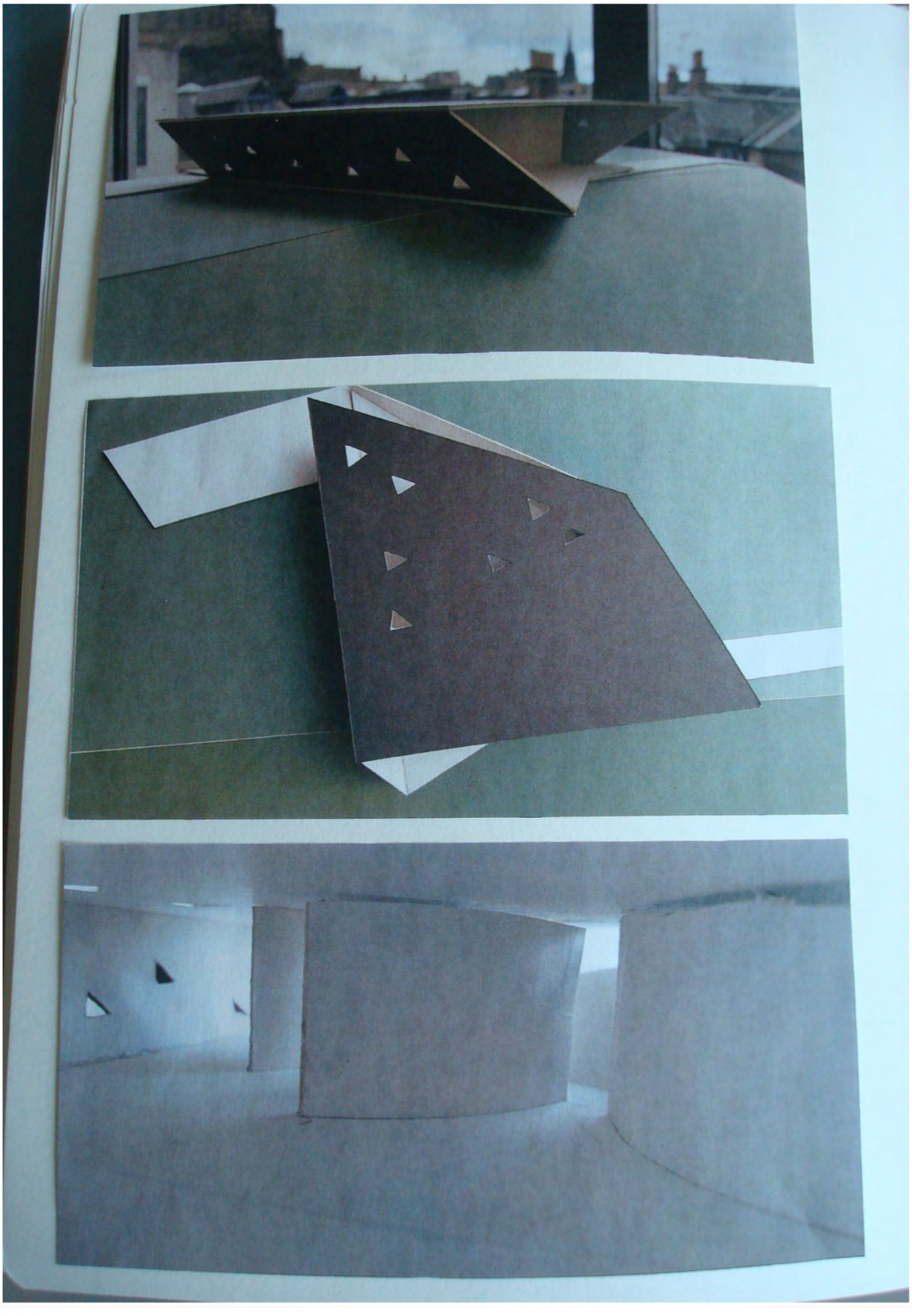
Pilot Study Workshop Set 1 Participant Results:

Maggie's Centre Fife



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Pilot Study Workshop Set 1 Participant Results:

Maggie's Centre Fife

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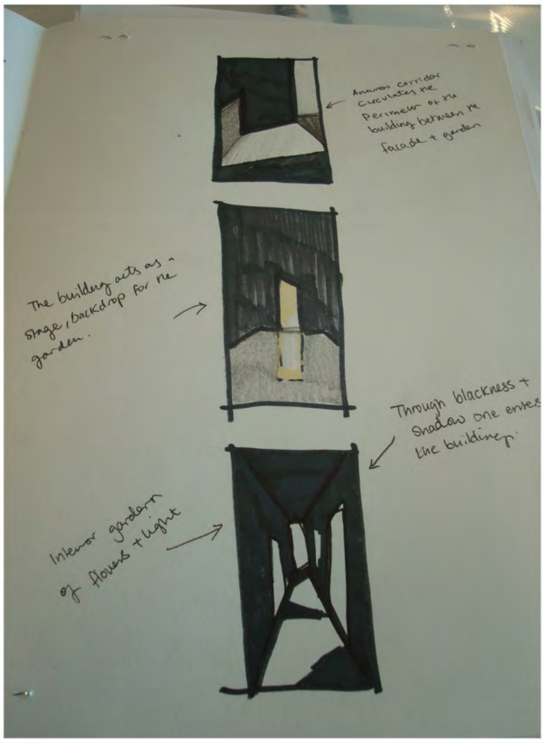

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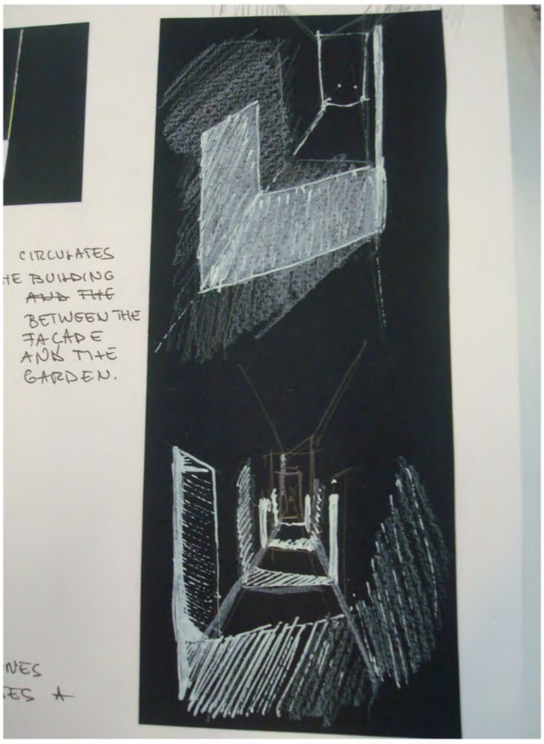

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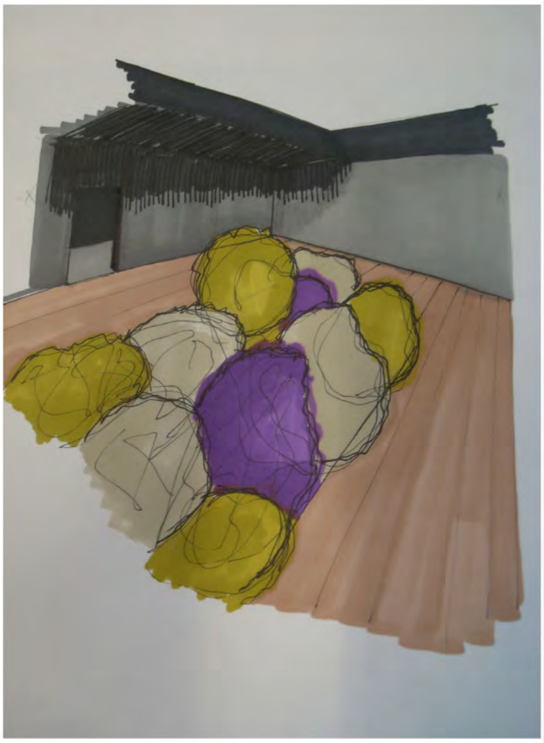
Pilot Study Workshop Set 1 Participant Results:

Serpentine Pavilion



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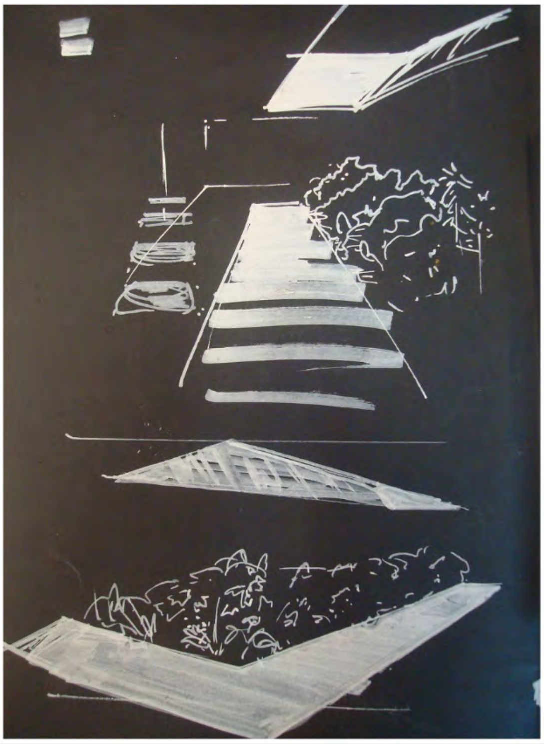

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Pilot Study Workshop Set 1 Participant Results:

Serpentine Pavilion

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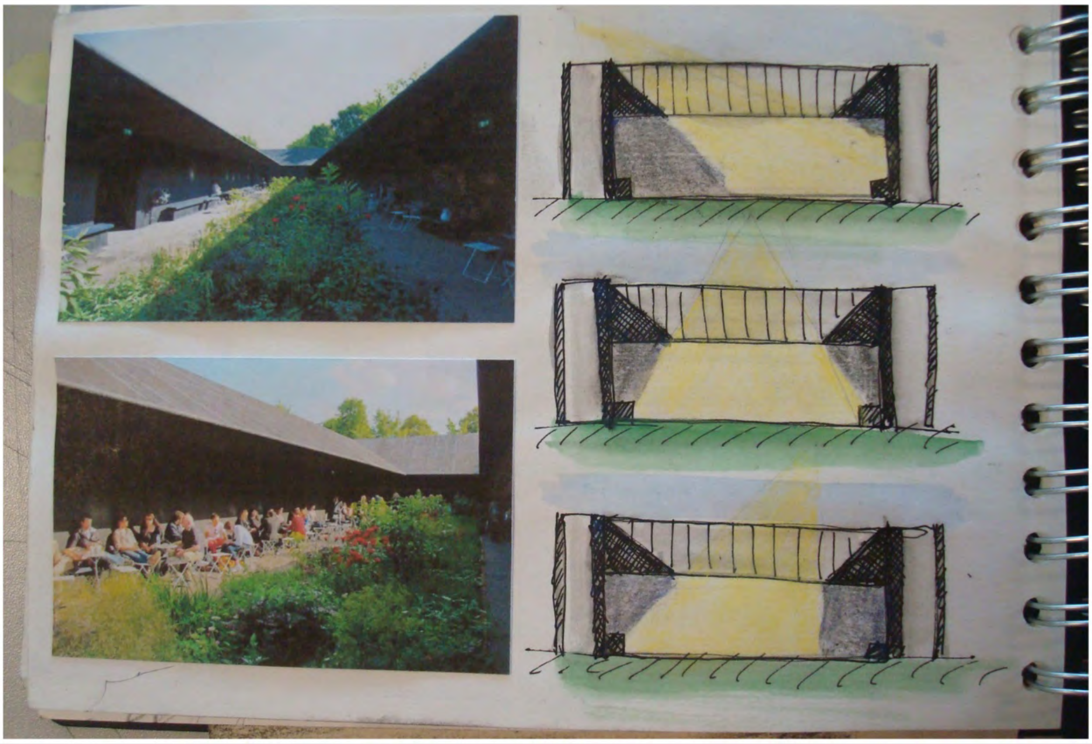

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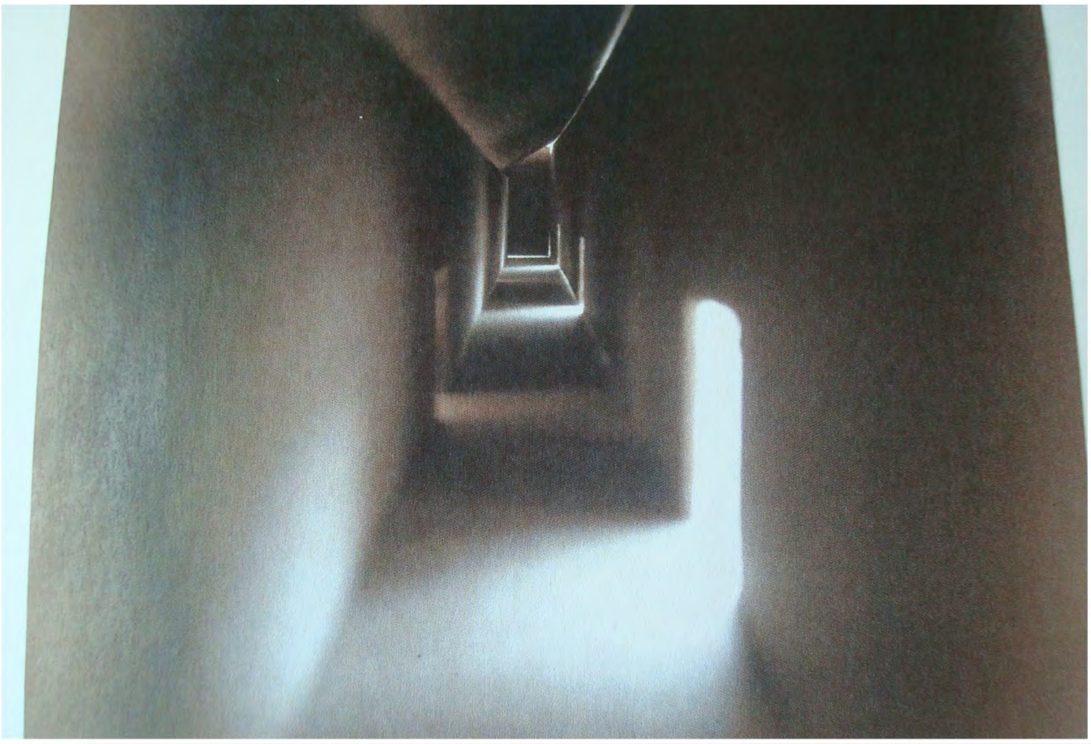
Pilot Study Workshop Set 1 Participant Results:

Serpentine Pavilion



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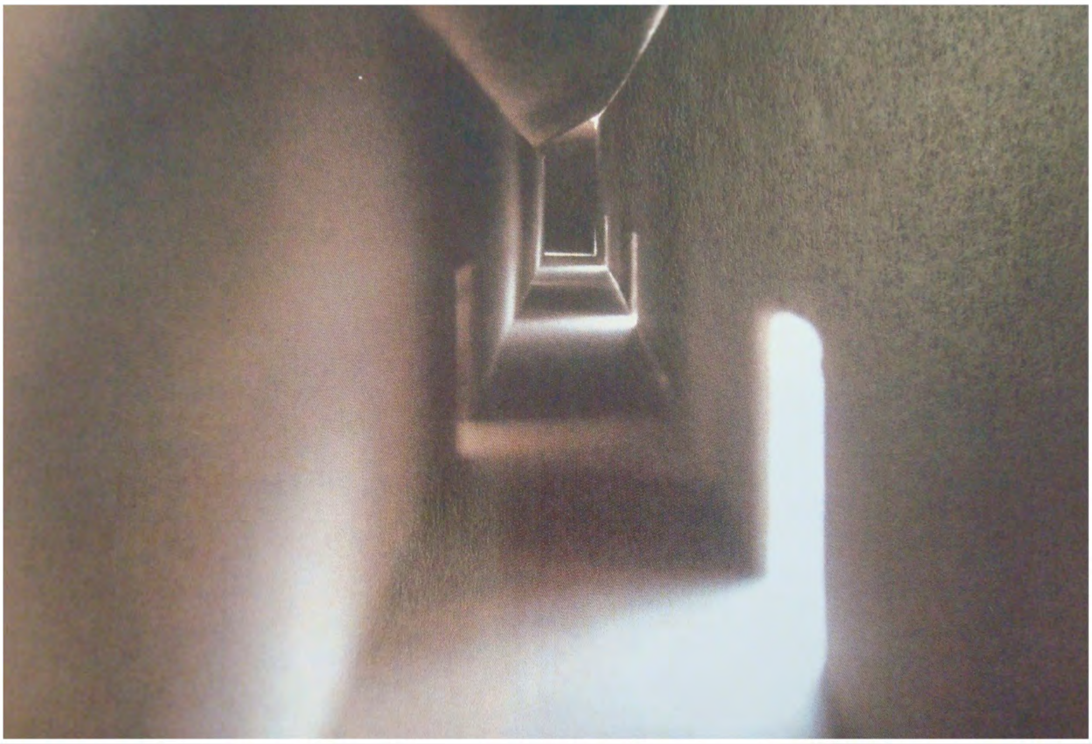

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Pilot Study Workshop Set 1 Participant Results:

Serpentine Pavilion

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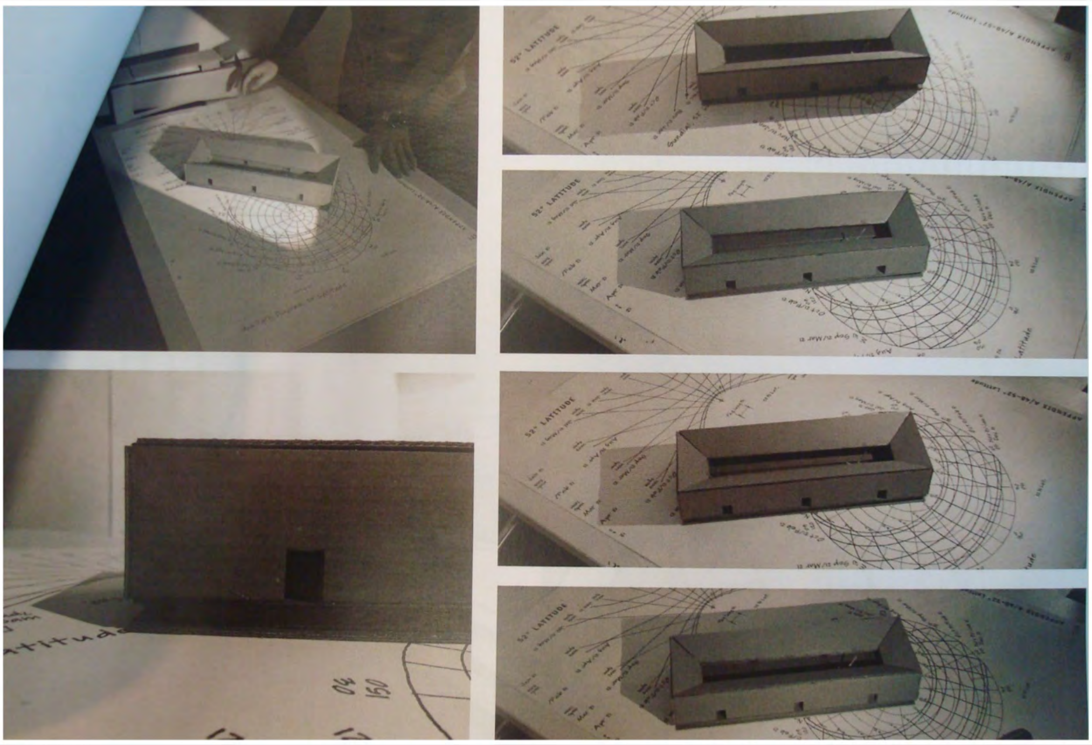

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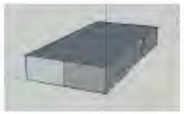
Pilot Study Workshop Set 1 Participant Results:

Serpentine Pavilion



TUTORIAL PREPARATION:
SKETCHUP TO VIRTUAL ENVIRONMENTALANALYSIS

PREPARATION FOR VIRTUAL ENVIRONMENTAL ANALYSIS WORKSHOP ON 22/10/13.

The software we will be using in our environmental analysis workshop allows importing of 3D models from SketchUp. In preparation for this, a SketchUp model will be uploaded to Learn for your use.

If you wish to analyse the building form you have designed for Assignment 1 this is possible as you are welcome to create your own model from scratch to use at the workshop. If you are keen to try your own model please ahere to the recommendations on the following page when creating your Sketchup model.

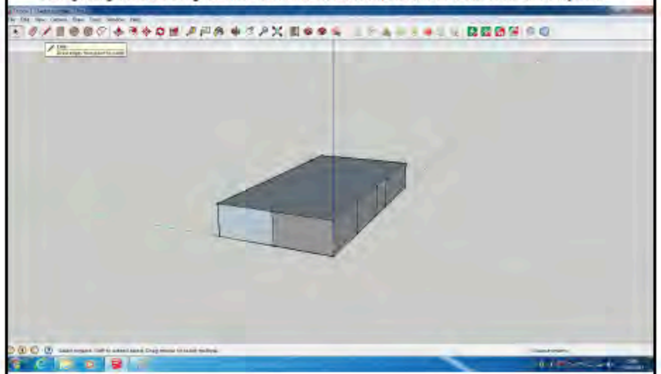
PREPARATION FOR VIRTUAL ENVIRONMENTAL ANALYSIS WORKSHOP WEEK 6.

The following rules must be applied when building or amending your model for use with IES VE:

1. Create only the basic volumes necessary, avoiding complex configurations and ensure each space (or volume) is fully joined at walls, floors and ceilings with no gaps
2. If you have columns in your space please omit these as IES will treat each column as a room!
3. Use only the "pencil" and/or "arc" tools to create your model as a series of planes with no depth or wall thickness.
4. Do not use any wall thicknesses but rather imagine your building as "paper" thin (use internal dimensions to create the volume).
5. Do not model the doors unless they are glazed
6. All glazed areas should be applied with a "transluscent" material within SketchUp

The following pages show screenshots of the process of preparing a SketchUp model template for use at the IES VE workshop.

1. Open SketchUp and click "file" and "open" your chosen model. Revise floor/wall/window dimensions and locations by deleting/adding lines and drawing new ones with the "line" tool. To delete, click on the line and "delete" on the keyboard.



Pilot Study Workshop Set 3 Presentation

19. Now please adapt your model to modify the daylight factor result. Select which components to revise to increase or reduce your Average Daylight Factor result.

20. Your analysis is now complete. Review your findings and try repeating with alternative fenestration, a different orientation and/or lighter/darker internal surfaces and consider these revised findings.

Now please complete the questionnaire:

How easy was this tool to use? Very difficult/difficult/straightforward/easy/very easy

How easy was it to import the model from SketchUp? Very difficult/difficult/straightforward/easy/very easy

Were the written worksheets/guidance notes helpful? Very helpful/helpful/ not very helpful

Were you given enough time in the tutorial to gain a basic understanding of the tool? Yes/No

Did you come across any significant problems? Yes/No

If so, what were these? Please note these on the back of the sheet.

Did this tool provide you with useful information for your project? Yes/No

If not, what would you have liked it to provide? Please note below:

Have you enjoyed testing this tool? Yes/No

Will you use this tool again to analyse your design studio projects? Yes/No

Pilot Study Workshop Set 3 Workshop Notes

SUNLIGHT + DAYLIGHT

LIGHTING ANALYSIS OF THE CHAPLAINCY

In your studio groups complete the tasks below. If you wish, tasks can be carried out as pairs within a group. Some of these tasks may be useful analysis tools for your microclimate pavilion analysis report (assignment 1)!?

a. Find the locations, when seated, where you can no longer see the sky "no-sky line". Refer to page 3 of these notes for a reminder. Mark out these areas on the plan by shading them. How dark does it feel in these areas?
b. Draw the light and shadow in the space as a sketch drawing using the blackpaper and chalks provided. Think about hierarchy of litsurfaces.....
c. Calculate the "Average Daylight Factor" for the space using the Littlefair/Plymouth formula overleaf . Don't forget to use the tables in the workshop booklet for values that you can't work out!
d. Test the real daylight factor value for the chaplaincy using point measurement and measurement tools. Measure the illuminance level inside and simultaneously have a partner measure the outside illuminance level.Select 4 points in the room you think are most important to measure (eg. darkest point/lightest point). Note these points on your group plan drawing. Now calculate a daylight factor value for each by dividing the internal by the external Lux value to achieve your daylight factor value. If using EdenApp please consult the tutors who can help you with your results.

SUNLIGHT AND DAYLIGHT WORKSHOP TASK - A

NO-SKY LINE

"If a significant area of the working plane lies beyond the no-sky line the distribution of daylight in the room will look poor and supplementary artificial lighting is likely to be needed."

SOURCE: LIGHTING SKETCHBOOK, G.TREACY

SUNLIGHT AND DAYLIGHT WORKSHOP TASK - C

AVERAGE DAYLIGHT FACTOR

Using the Littlefair/Plymouth expression –
suitable for side-lit rooms of simple configuration:

AVERAGE DF = $\frac{T \times W \times \theta}{A(1-R^2)}$

T = diffuse transmittance of glazing material
(eg. 0.7 for double glazed clear glass)

W = total glazed area of windows in the room
(eg. 2.9 high x 7m south wall x 7m east wall x 2m northwall)

θ = angle of unobstructed view of sky from centre of the window (in section) in degrees. Use your section drawing to check this angle. Choose façade with worst case (smallest angle). Eg.Approx 30 degrees @ north façade for ribbon window.

A = area of all room surfaces (eg.Floor 30sqm + walls 10m length x 2.5m high (x 2 walls) + walls 3m length x 2.5m high (x 2 walls) + ceiling 30sqm).

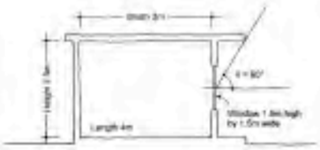
R = the area weighted reflectances of all room surfaces (eg.0.3 for dark grey flooring, 0.8 for white walls/ceiling).

Pilot Study Workshop Set 2 Workshop Notes

QUANTIFYING DAYLIGHT – AN EXAMPLE

Example section - ensure you measure all these dimensions for your own building; height (floor to ceiling), width of room, length of the room, total of all glazed areas and clear visible sky angle considering any overhangs (as shown below). Note: with this field study, these dimensions will only be approximate.

APPENDIX B 251



B.2 Daylighting for side-lit interiors.

RANDALL, T, ENVIRONMENTAL DESIGN, 2006, APPENDIX B

QUANTIFYING DAYLIGHT – AN EXAMPLE

Let us assume that :

"τ" (transmittance of glazing) = 0.75

Reflectance of the ceiling finish = 0.7

Reflectance of the internal wall finish = 0.5

Reflectance of the window = 0.1

Reflectance of the floor = 0.3

The total area of the room is 59sqm. The average reflectance is area weighted in the following way:

(Reflectance of side wall) x (area of side wall) = (0.5) x (3 x 2.5) = 3.75

(Reflectance of side wall) x (area of side wall) = (0.5) x (3 x 2.5) = 3.75

(Reflectance of back wall) x (area of back wall) = (0.5) x (4 x 2.5) = 5.00

(Reflectance of front wall) x (area of front wall) = (0.5) x (10-2.25) = 3.88

(Reflectance of window) x (area of window) = (0.1) x (2.25) = 0.23

(Reflectance of ceiling) x (area of ceiling) = (0.7) x (4 x 3) = 8.4

(Reflectance of floor) x (area of floor) = (0.3) x (4 x 3) = 3.6

TOTAL = 28.61

RANDALL, T, ENVIRONMENTAL DESIGN, 2006, APPENDIX B

QUANTIFYING DAYLIGHT – AN EXAMPLE

Then,

$$R = \frac{\text{Area weighted reflectance value of } 28.61}{\text{Total room surface area } 59} = 0.48$$

And

$$\text{Average Daylight Factor} = \frac{0.75 \times (2.25) \times (80)}{59 \times (1-0.484)} = 2.2\%$$

Therefore, in conditions of a standard overcast sky of 5000 lux, the average light level would be 5000 x 2.2% = 110 lux

RANDALL, T, ENVIRONMENTAL DESIGN, 2006, APPENDIX B

QUANTIFYING DAYLIGHT

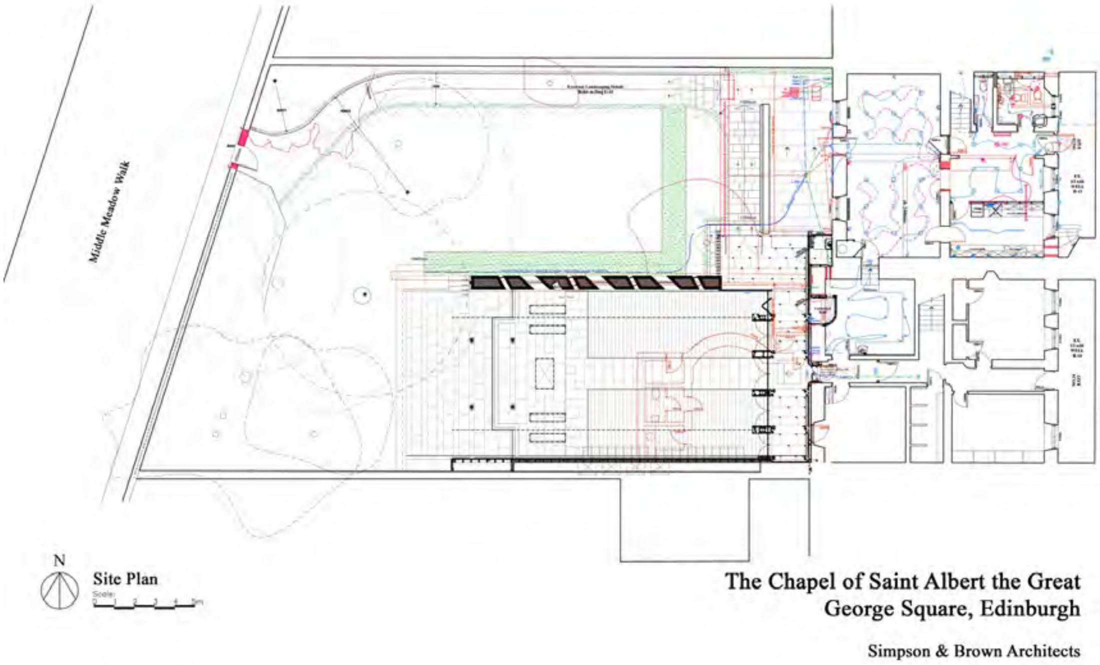
Data sheet Typical *reflectance of materials under diffuse daylight*

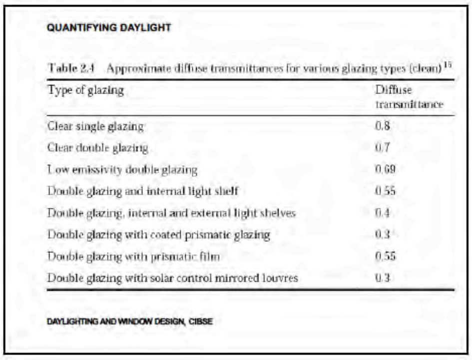
White paper	0.8
Stainless steel	0.4
Cement screed	0.4
Carpet (cream)	0.4
Wood (light veneers)	0.4
Wood (medium colours)	0.2
Wood (dark)	0.1
Quarry tiles	0.1
Window glass	0.1
Carpet (deep colours)	0.1

Paint colours, with Munsell reference	
White N9.5	0.85
Pale cream 5Y9/2	0.81
Light grey N8.5	0.68
Strong yellow 6.25Y8.5/13	0.64
Mid-grey N7	0.45

DAYLIGHTING – TREGENZA & LOWE

Pilot Study Workshop Set 2 Workshop Notes



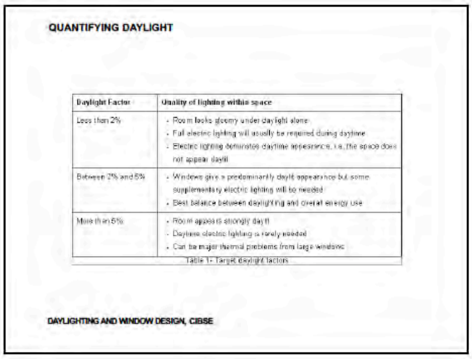


QUANTIFYING DAYLIGHT

Table 2.4 Approximate diffuse transmittances for various glazing types (clean)[15]

Type of glazing	Diffuse transmittance
Clear single glazing	0.8
Clear double glazing	0.7
Low emissivity double glazing	0.69
Double glazing and internal light shelf	0.55
Double glazing, internal and external light shelves	0.4
Double glazing with coated prismatic glazing	0.3
Double glazing with prismatic film	0.55
Double glazing with solar control mirrored louvres	0.3

DAYLIGHTING AND WINDOW DESIGN, CIBSE



QUANTIFYING DAYLIGHT

Daylight Factor	Quality of lighting within space
Less than 2%	- Room looks gloomy under daylight alone - Full electric lighting will usually be required during daytime - Electric lighting dominates daytime appearance, i.e. the space does not appear daylit
Between 2% and 5%	- Windows give a predominantly daylit appearance but some supplementary electric lighting will be needed - Best balance between daylighting and overall energy use
More than 5%	- Room appears strongly daylit - Daytime electric lighting is rarely needed - Can be major thermal problems from large windows

Table 1- Target daylight factors

DAYLIGHTING AND WINDOW DESIGN, CIBSE

Pilot Study Workshop Set 2 Workshop Notes

Pilot Study - Focus Group **Example 1**

19/03/16

In attendance:

Focus group Facilitators: (SF)

In adjacent area: (GT).

Note: Text in yellow was used for NVivo coding/language analysis

SF: Tell me about your lighting sketchbook?

Student: This was for the time of day and the time of year and its specific position, where it is in the world.

SF: Did you have an interest in this, do you remember the time?

Student 1: We did quite a few different ones, we sort of experimented with...emm do you remember (to a colleague) ...

Student 2: Yes, hmmm, October 21st 12, 3pm,

SF: For example this one you have?

Student 1: Well, it was really tricky, that one wasn't based on the..., that was just in the studio, I just had it kind of had it facing the window, just to see what the light would look like inside. It was about now, last week this time, about 11 o'clock. That one wasn't on the actual sunpath. It was a made up time.

SF: Do you have other drawings, anything else?

Student 1: Not particularly, I've not really got much else with me.

SF: Was it the physical model you prepared?

Student 1: Yes, it was mostly the model I concentrated on.

SF: Was it worth making the model, what did you find out making the model?

Student 1: Yes, definitely. I really like making models in general. I find it a good way of getting involved in the building. Have a look at just little things like this, this little bit was quite tricky, where it rises up on the slope there, like where this wall rises up, just to get an idea of how that might work in real life. When I first started making it I hadn't really thought about that, how you make it on section, in the section you can see the slope, but I didn't really think about how that would change once you had that wall. I thought that was quite interesting.

(shows model around the whole group)

SF: What else did you find from the model? Was it useful for anything else?

Pilot Study Focus Group – Example 1

Student 1: Yes, definitely. Without a doubt, to give you an idea of how long the space is compared to how thin this little cross at the front is. It gives you a line of light. You can imagine, well you can't see all that well on the image what the light is like back there because of the light coming in there but I don't think that happens in real life. It would be really bright then dark next to… it is interesting to get an idea of the size of the space.

SF: Do you think the accuracy of the models was a problem? Was anyone concerned by that?

Student 1: I think once it got smaller…because I did have a go at making some of the seats it got super fiddley, but I suppose that gives you an idea of the size of a person .

SF: I'm thinking that if you make a model so quickly and roughly that you are getting light inside that you wouldn't expect in reality, do you think that's an issue.

Student 1: Yes, guilty!

Student 2: I think, yes, getting light in somewhere else then the strength of the cross is not possible.

Student 1: I think especially with something like that that is a dark kind of potentially cold space, having other light coming in wouldn't really show what it was going to be like.

SF: OK so maybe this model then, it has a lot of daylight in it anyway, would it be less obvious do you think?

Student 1: I think it very much depends on the space itself. So yeah, we should have taped up the sides or something…if we look at that image anyway we can see light coming in at the top, I suppose that's the issue.

SF: For this project you were making a model focussing on the lighting, but, with your own models, for your own projects, do you feel you would need to make another model to do that?

Student 3: We have one, it's 1:200, we can use it OK.

Student 4: Material-wise it's a bit tricky, and it's so small, for the camera and photos. You have to cut the model but then how do you deal with the light? I think there is an issue with scale and size when you want to do the models for light. At least, that what I think.

Student 1: I found it really useful though for the Fruitmarket because of the way the two roofs and the two big slits go right the way along it but until I made the roof, it was pretty much useless but once the roof was on it gave you a much better idea of what light you would be able to get into the rooms and the upstairs spaces which was really helpful. To decide where the rooms were going to go in our hotel project…

SF: Do you want to discuss yours?

Student 5: Well I've got these sketches of the church of light, I didn't look so much at the light but at the site analysis of it…and how that makes light come from a certain direction. I tried to explore what the light was like inside. Yeah that was using watercolours so, I also looked at how the light would look coming out from the inside. These are also CAD images of the space in Sketchup. I tried doing it with the plan to match the actual location, aligned with the North axis as well, I got that

Pilot Study Focus Group – Example 1

from Google maps and stuff. I was using my model and unfortunately I just typed in the name and it was there so I thought I'd just use that...!

SF: Did the model you found have the adjacent building?

Student 5: It didn't.

SF: So, was there any point in doing that?

Student 5: Well, you're getting an idea of the lighting inside the box, I'm not too sure how accurate the lighting was because if you change the like light and dark it would have shadows on the inside but then on the other hand it would just eliminate a whole wall which was a bit confusing...

SF: I'm also interested in your sketches. It would be interesting to know what was your guide to how the light would be?

Student 5: I just tried to envision it myself. It's not great.

SF: That's a brave thing to do, on your section. It is difficult.

SF: Did you try it on plan as well? That is a difficult thing to imagine, the light on the floor...

Student 5: Yes, it's not good.

SF: It doesn't surprise me that you are maybe not as happy with the results you got from that, it is actually a lot more of a challenge to do.

Student 5: I don't normally use this watercolour stuff...

SF: No, that good to see, trying out other ways. What do you prefer do you think? Do you prefer the images that you are getting through Sketchup? Or do you prefer having things that are a bit more sketchy?

Student 5: Well there's a difference so when you are doing like a project and you concentrate on computer models you have more accuracy, a more accurate representation of the space. Visually sometimes, I remember from my last project in studio, when we were designing for the Cyrennians, when I remember going back there, and thinking, wow there is actually hardly any space here so... it helps.

GT: Thanks everyone for participating

Pilot Study Focus Group – Example 1

Pilot Study - Focus Group **Example 2**

19/03/16 MVI4270

In attendance:

Focus group Facilitators: (SF), (EV)

In adjacent area: (EV).

EV: OK I have it all now.

Student: It shows light coming in to the building. This other one is I think August, and I took it early in the morning. It shows basically that this building would work well in the morning if it was built in Edinburgh. Any other time or period of the year, not really….and that was our investigation.

Student: I have the sketches of the light in the church…

EV: So from those drawings that you did, you tried a couple of drawing techniques, which was most successful for representing light?

Student: I think the actual model…and I wasn't sure like, like when we did it I realised how much it helps just to imagine how the light works. So I think even when you see the photos of the real building…I think seeing the model is a totally different experience, so like seeing the model and I don't know, like trying to draw it I think understand the light it becomes much, much better and working with the light is much, much better. I think it helped a lot. Even if you see the photos from all the different angles and seeing it in a kind of real object it was totally different. It was more easy to imagine how the light and shadows work, at different angles. And I think you are going to see the shadows and how this bit of the garden is always in shadow.

EV: I am extremely interested about this, what the meaning in that you didn't chose black, in that the pavilion was black. I think it was, with this model, with this decision you are re-conceptualising a re-approximation of the real material, how conscious or how important for you was it not to use black?

Student: I think it was just like an experience, to use white, and see, you know, how exactly, see more clearly how the light is going in. I think when you have black colours sometimes the shadows blur so it was just like an experiment. But I think he chose black to provide more drama so we thought let's do the opposite and see what it looks like in having the white cardboard. And I think black looks a bit better!

EV: Because I think other experiments would have been to try ink or other so I think it was, I don't know but I would be cautious but we could try to say OK we can analyse it in different textures…The good thing about it is that the particular aspect of this element compared to the other two is that it was a temporary pavilion so it has this sense that you can play.

EV: It may be interesting to look at all the models that were made of this? OK so that's your one. So, you chose not to use black as well…. How did you feel that worked? Were you getting images of the inside through the lense? Or images that were like the photos shown in the lecture?

Pilot Study Focus Group – Example 2

Student: We couldn't get a camera in so we used it for more of an overall site study. I think for us we realised that the material was more of a sort of matt and not reflect much. So we were also experimenting with the materials.

EV: Can you show us your sketches?

Student: ....

EV: So you were working with quite a lot of drawings using black as the base and applying white on top?

Student: Yes, it was my way...

EV: So how about this one then, who worked on this one?

Student: Us four

EV: OK, so you were doing some hand drawings too? Do you have some pictures of this model?

Student: Yes some here...

EV: So did you draw what you were seeing inside the model at all?

Student: Yes, well I've not quite finished this...

EV: So those drawings are based on images from the ones shown in the lectures, yes?

Student: Yes. We have still to test it.

EV: Oh have you? OK, so you will need to do this and then decide what you wish to show.

EV: OK, would you like to tell the others what you have been working on?

Student: So I was mainly looking at the lighting and trying to analyse different ways of doing that in my drawings. So I've mainly just down watercolour and yellow to show the flow of light. I'm a little bit stuck in my ways! We didn't get to do the photographs inside it yet...

EV: It will be interesting to see what you do with the roof as well because...making sure you're not getting light leaking in, depending on your accuracy. So, I appreciate that sometimes you can make models early on that are rough, ready and quick or you spend ages using a lot of card and make it very precise. The challenge is at what point is the model suitable enough to test? Or how precise does it need to be in order not to get cracks where the light might seep in? Were you challenged by that in the models you were making?

Student: We were trying to find the right information to make the model. For us we had sections so we also made a lot of assumptions. But it was interesting from a construction point of view, I think it pushed us to try and understand where the shapes of the roof were and the triangulation. We did try and make sense of it and how the lighting was with the shape of roof.

EV: Do you want to talk to us about the project you were working on?

EV: This is your model? Have you got the results with you?

Pilot Study Focus Group – Example 2

EV: So these are the photos of the space inside?

Student: Yes, yes.

EV: And what days or times of year did you test?..What are these pictures of?..Do you know what month it was, or time of day?

Student: Some day in March maybe afternoon.

EV: Because choosing the times to test can be quite important because, for instance, with the Maggie's Centre it is not normally open until 9 or 10 o'clock in the morning. So when you do your testing there may be no point in trying 8am on the 25th of December, right, because there would be no one there? So you pick times, so when you analyse your building, try and think of the times when you actually may be using it, like when the lighting in the space will be important and that will cut down the actual amount of times you need to test for.

EV: OK, do you feel these model photos are atmospheric? Would a sketch convey more atmosphere than the model photos or not?

Student: I think getting the camera more inside, not sitting outside it has no atmosphere. I think it can be better to see the interior. Yes, it is actually too far.

EV: Do you think with the sketching you have a distance from it still?

Student: Yes. I think they are really good (talking to a model). I think you really feel like you enter there...yes, like this (talking to a sheet of b/w photos), exactly.

EV: Is it because when we are closer inside it feels more realistic?

Student: I think it feels more in scale. When you are far away I don't think you feel the interior of the space. As you start to get closer it starts to feel...

EV: I think in the experiments it is good to get an element of human scale, perhaps you get atmosphere if someone is walking there, the same in the sketches, if someone is dwelling there. OK...

EV: OK. Are there other drawings to see?

EV: OK, you are using hatching on your drawing? Which technique or way of drawing did you like best?

Student: The marker pen. These are different drawings showing the light with the pen, or I show the shadows with the pen actually.

EV: On section too? Any preference for pink there, as light?

EV: Could it have been green...or orange?

Student: hmmmm

EV: Did anyone try the Photolux app, to show the luminance values?

Pilot Study Focus Group – Example 2

Students: ……..

EV: I thought I tried it with some of the groups in here?

Student: I couldn't download it on to my phone, from the app store.

Students: No, we didn't use that app.

EV: Does anyone else have any drawings to show?

Student: I have some line drawings…

EV: So you are using mostly pencil. Do you like this technique best?

Student: Yes

EV: Did you try anything else?

Student: Emmmm…no. Pencil is very quick for me.

EV: OK. So this works for you already. Have a go, and try another technique.

EV: So you were all making this big model here then? How long did that take to make?

Students: One day

EV: So did you find the model a useful thing to make?

Students: It was the most work working out the diagram drawings for the roof but that was the best thing to see with the light coming in.

EV: For those of you who tested your model did you use the nomen or another way to work out the sun path.

Students: Nomen, the little pin.

EV: So no one tried the stereographic sunpath chart? The one where you find the plan angle and the altitude?

Students: No, no. The shadow pin was quicker…and much easier because you didn't have to work it out. Yes, all the lines on the chart are confusing…I understand them but it is too complicated.

EV: And did anyone use the model viewer?

Students: Did you use that?…it looks like this…yes.

EV: Does anyone have anything else in their sketchbook they wish to show?

Student: I am showing different colours and shapes to show the light.

EV: I see in that corridor there are about six or seven different tones used.

Pilot Study Focus Group – Example 2

Student: And this one I feel is interesting because after I draw it it is very nice to ask "what is this building?". The openings in the Maggie's Centre…there is some of them are lighting and some of them are just glass openings but you cannot really tell what the openings are for, maybe they are skylights, maybe they are artificial lighting or they are just glazing for the landscape. Emm…

EV: Is this shading technique something you might use for a future project? Or do you tend to just do more technical drawings for your other projects?

Student: Umm…in my project we need to have some landscape drawings…

EV: And how do you normally do that?

Student: Mmmmm…just for the initial ideas I will use some pencil drawings, to help with the shape, with the shadows, and more and more, with materials and atmosphere with different colours more quick. If you want to present your work, after you really finalise it, you will come to more accurate drawing.

EV: OK, and would that drawing take longer to do, do you think, than the others?

Student: I think water colour is OK.

EV: Could I ask a general question? Did anyone build these models in a 3D software program of any sort, Sketch-up?

Students: No, well actually we did very quickly when we were studying it. We did not use Sketch-up but we did find a ready made model with the Church of Light so we did play around with it.

Student: It was a good thing to do because we could see from our head, we could position ourselves in the camera, so we could get inside it more…

EV: Did you print any of those images out?

Student: No, it was a very quick study.

EV: OK so it was a ready made model, there are a few out there. And did you check the orientation and how it works with the sun?

Student: Umm…I think it would have needed a bit more work on it to make it more accurate. It did have a north arrow.

EV: Do you want to show us your drawings?

Student: Yes. I don't use pencil I use pens. I use markers. I used a pen for these lines. I'm trying to show the different densities of light.

EV: OK, so your drawings look like they take a long while to draw?

Student: Yes! Really time consuming…

EV: Did you get the chance to look at any of the numbers relating to this? Illuminance levels, luminance contrast? The amount of light? Student: No, just with my pens.

Pilot Study Focus Group – Example 2

Chapter 6:

Main Research Workshops

Create Model: Studio

Model: Studio

Describe Workshop

Notre-Dame du Haut, Ronchamp

Transcript 2

4 mins

1. Participant 1: I have this one
2. Participant 2: Oh, it's a big church space?
3. Participant 3: Yes
4. Participant 2: The wall design is sort of geometric, have you listed that?
5. Participant 3: and the form of it
6. Participant 1: The wall design shows all these shapes…mmm…they are geometric..
7. Participant 3: what about the windows, are they coloured?
8. Participant 1: they're really nice, the windows…
9. Participant 2: Have you put that it is really contrasting on the list?
10. Participant 1: Yes, strong contrast actually…
11. Participant 3: What are those? (points to candelabra)
12. Participant 1: Just candles I think
13. Participant 2: ah…
14. Participant 1: they're probably for the church
15. Participant 2: I think it looks like you can get out at the end?
16. Participant 2: What do you think?
17. Participant 1: Any more about the religious thing?
18. Participant 1: Maybe…
19. Participant 2: I think you could put that there might be a door
20. Participant 1: OK
21. Participant 3: It's sort of alluring…
22. Participant 1: Yes
23. Participant 3: Now, what other things?
24. Participant 3: Have you talked about the coloured windows?
25. Participant 1: Yes, that is the main feature, the light coming through them
26. Participant 2: That's probably enough…that's a big list now…

Workshop 1 'Describe' Case Study 1 – Example Transcript

Describe Workshop

Case Study: The Church of the Light

Transcript 3

4 minutes

1. Participant 1: OK What is your picture? (takes picture over to see the right way round)
2. Participant 2: Have you written that it is a church then?
3. Participant 3: Yes
4. Participant 2: I think I would say it is sunny. Have you got that?
5. Participant 3: No, not yet (writing this)
6. Participant 1: I'm not sure, it is churchy so maybe religious?
7. Participant 3: I've put down religious already
8. Participant 1: I think you need to write about the shadows too…
9. Participant 2: That's a good idea
10. Participant 1: It is sharp cross, the light makes the cross
11. Participant 2: and it is coming right across the floor
12. Participant 3: fine…yes…(writing all down)
13. Participant 2: and the people are in the shadowy bit…
14. Participant 1: they're split down the middle…right?
15. Participant 2: OK what else?
16. Participant 2: I like your one!
17. Participant 1: Any more about the religious thing?
18. Participant 3: I have religious…
19. Participant 3: what about the window on the side, it is glowing
20. Participant 1: Well the room and the light together make the cross at the end…then the other window makes it brighter?
21. Participant 2: Yes exactly
22. Participant 1: Now I'm stuck with anything else (puts sheet in middle of table)
23. Participant 3: OK leave it now.

Workshop 1 'Describe' Case Study 2 – Example Transcript

Describe Workshop

Case Study: Bruder Klaus Chapel

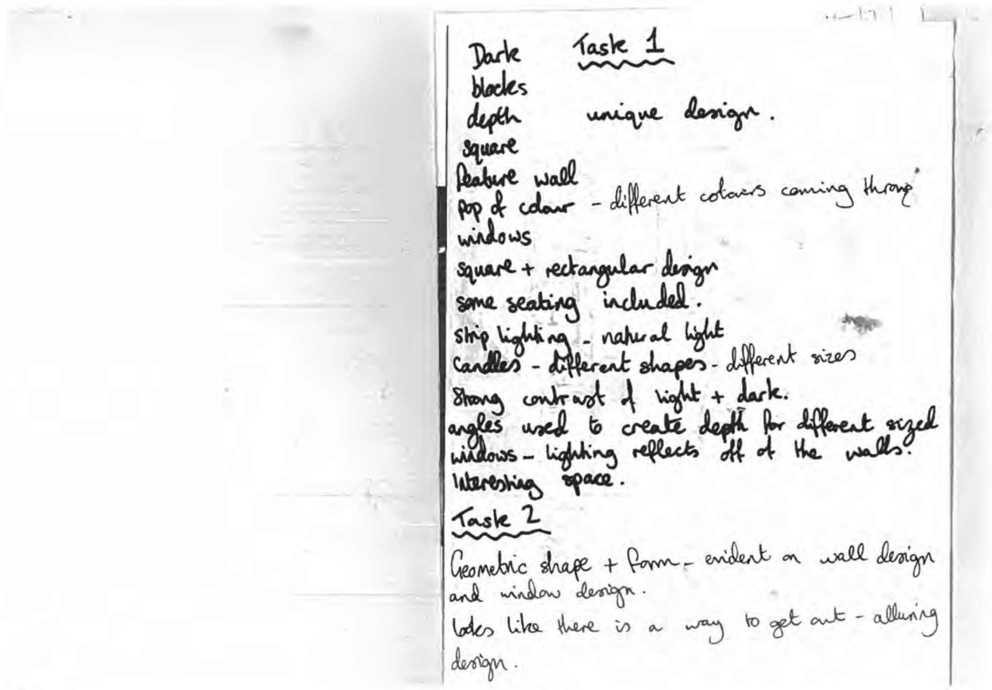
Transcript 4

2 mins 10 sec

1. Participant 1: this is a strange one… (turning it in lots of different directions)
2. Participant 2: What do you think it is, a sculpture?
3. Participant 3: I think it is an open ceiling…like not indoors?
4. Participant 2: It doesn't matter what the space is I suppose?
5. Participant 1: I've just been describing it…like…narrow with skylights…
6. Participant 1: It's got these white dots on it…can you see them..?
7. Participant 2: They look like bits of sculpture, maybe say that
8. Participant 3: It's very dark with this really strong light from above
9. Participant 2: I think the white dots are like those cats eyes you get
10. Participant 1: That's maybe right…it does look like they are shiny
11. Participant 2: mmm…why don't you write about the bumpy texture too
12. Participant 3: They are very big…maybe metal ridges?
13. Participant 1: I haven't said
14. Participant 2: What about the strong light, have you written that?
15. Participant 1: Yes, I wrote about it being dramatic
16. Participant 3: It definitely feels creepy…is it a tomb?
17. Participant 1: Oh, I know like one of those stone things…
18. Participant 2: No, it feels like a bit space
19. Participant 1: Do you think so?
20. Participant 1: I wrote it was narrow
21. Participant 2: That's probably OK then
22. Participant 3: Maybe it's a sundial shape?
23. Participant 1: No I don't think so, the light is just coming in…like a skylight

Workshop 1 'Describe' Case Study 3 – Example Transcript

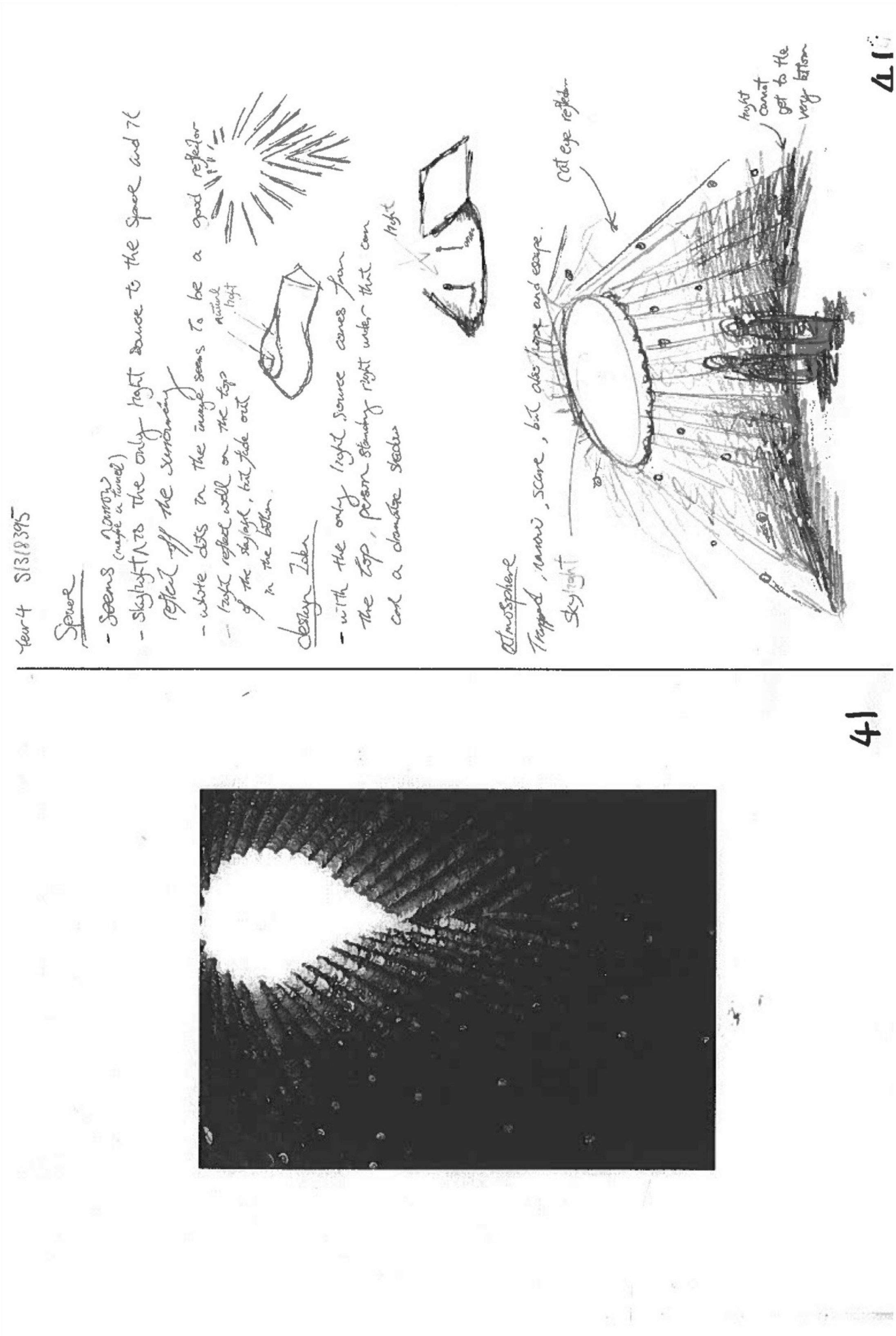
A



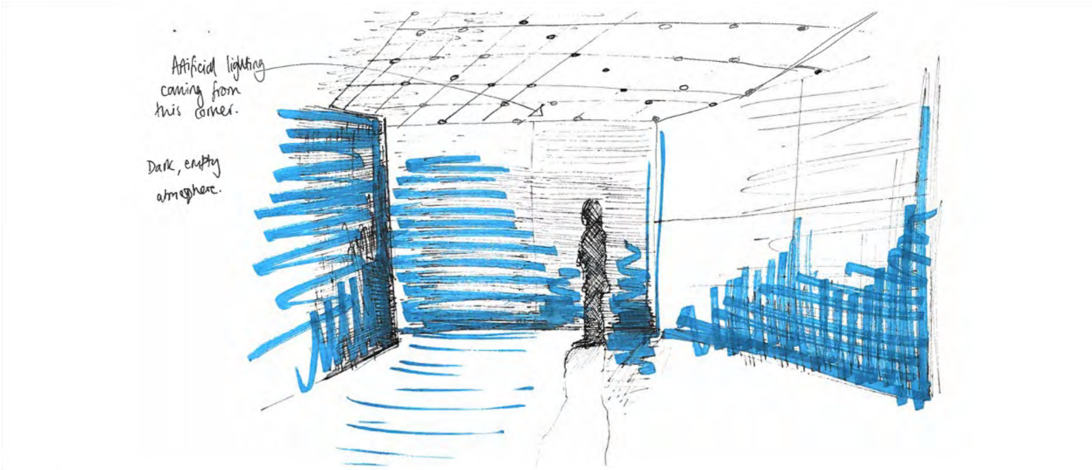
Dark Task 1
blocks
depth unique design.
square
feature wall
pop of colour - different colours coming throug
windows
square + rectangular design
some seating included.
strip lighting - natural light
candles - different shapes - different sizes
Strong contrast of light + dark.
angles used to create depth for different sized
windows - lighting reflects off of the walls.
Interesting space.
Task 2
Geometric shape + form - evident on wall design
and window design.
looks like there is a way to get out - alluring
design.

B

Workshop 1 'Describe' Case Study 1 – Participant Results



Workshop 1 'Describe' Case Study 3 – Participant Results



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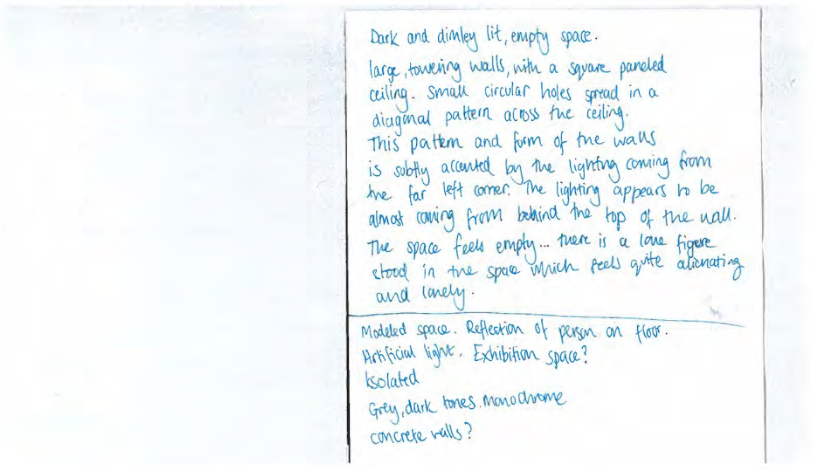
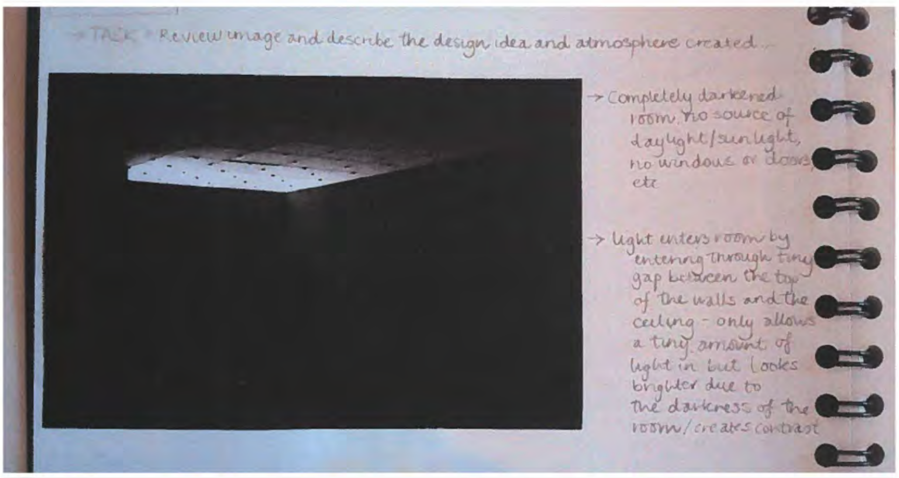


Dark and dimley lit, empty space.
large, towering walls, with a square paneled ceiling. Small circular holes spread in a diagonal pattern across the ceiling.
This pattern and form of the walls is subtly accented by the lighting coming from the far left corner. The lighting appears to be almost coming from behind the top of the wall.
The space feels empty... there is a lone figure stood in the space which feels quite alienating and lonely.

Modeled space. Reflection of person on floor.
Artificial light. Exhibition space?
Isolated
Grey, dark tones. Monochrome
concrete walls?

B



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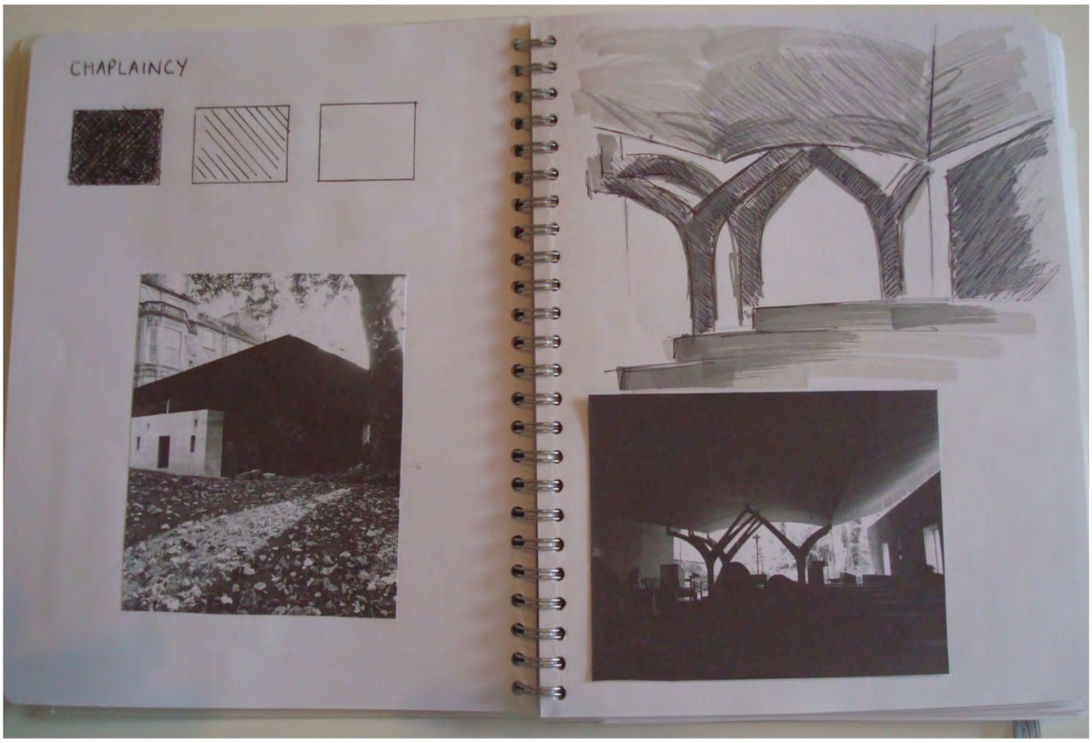
Workshop 1 'Describe' Case Study 4 – Participant Results



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Workshop 2 'Field Visit' – Participant Results

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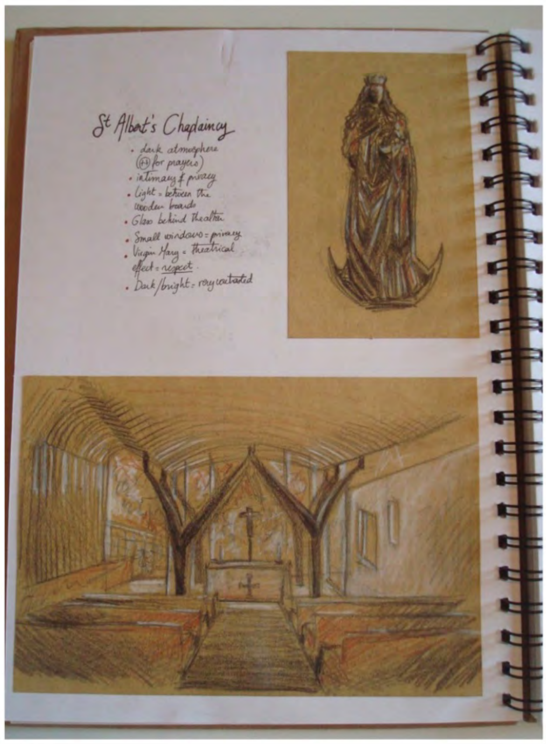

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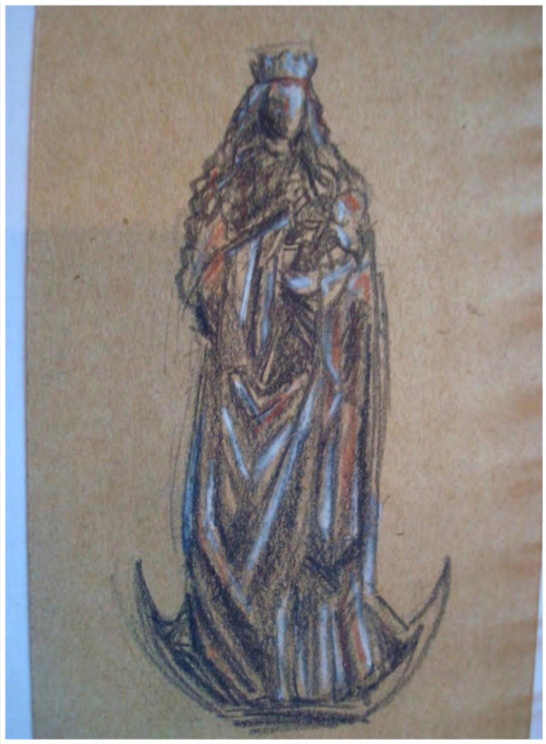

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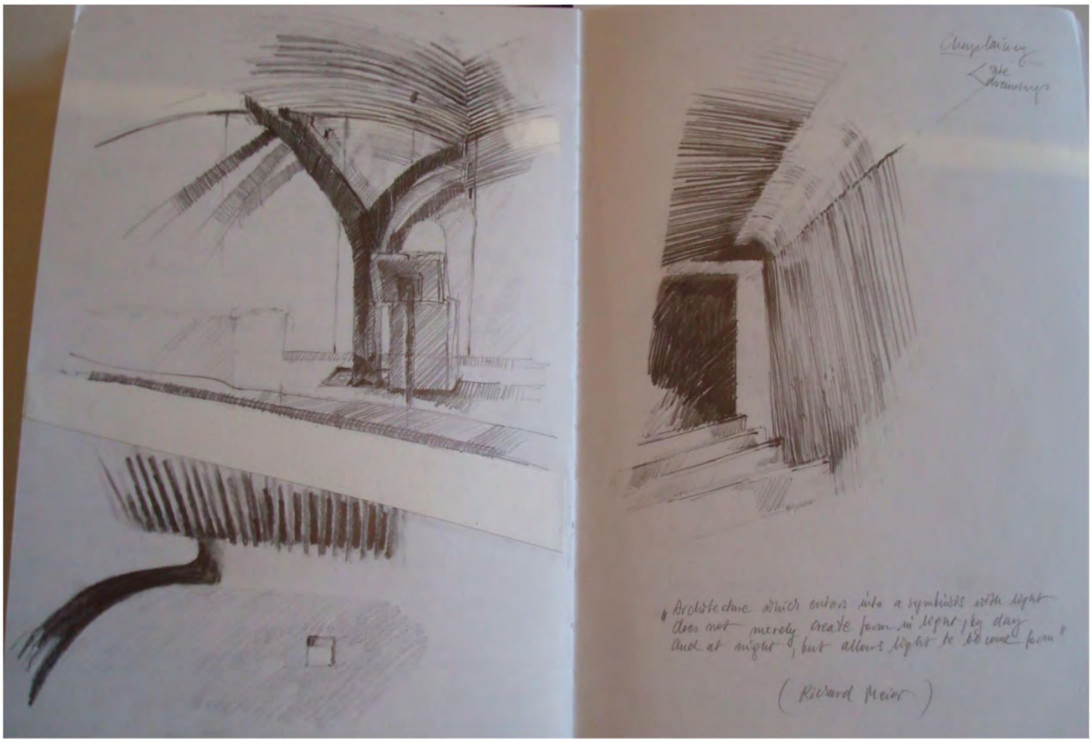
Workshop 2 'Field Visit' – Participant Results



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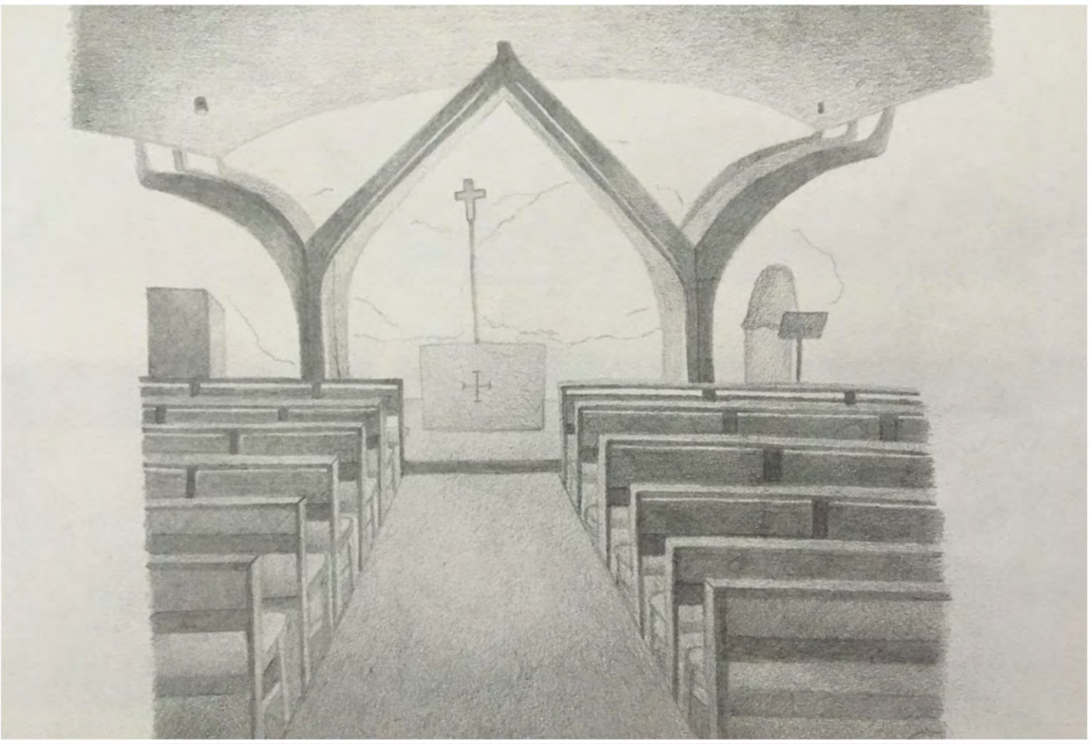
Workshop 2 'Field Visit' – Participant Results



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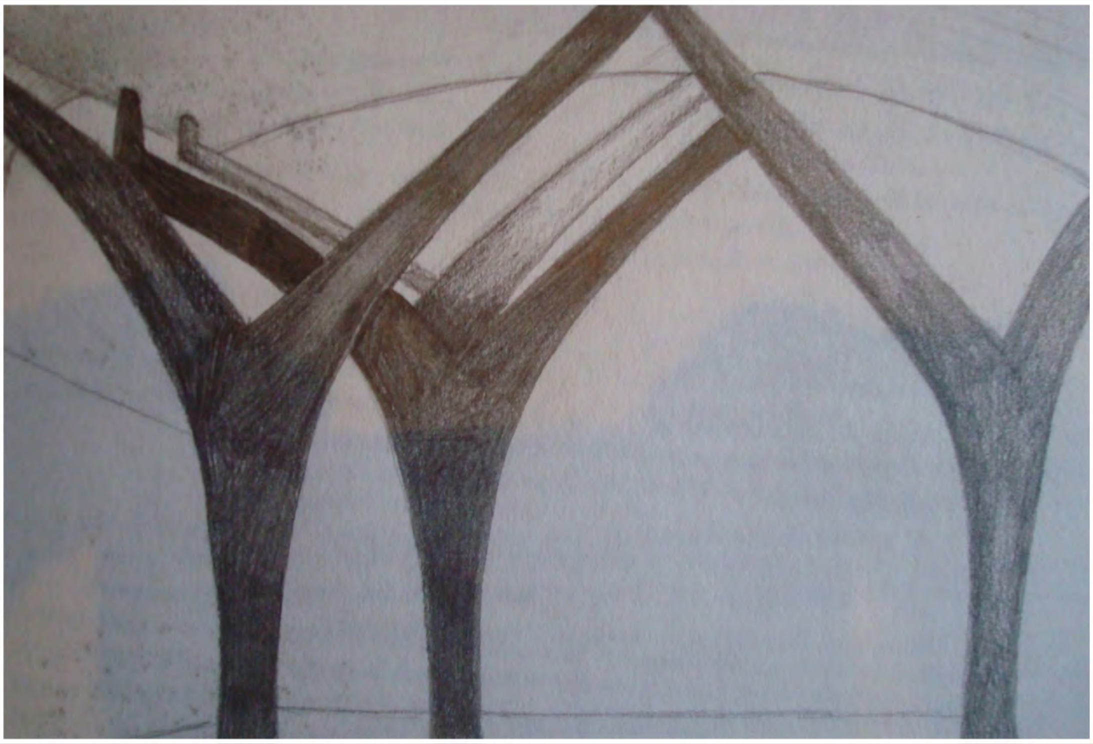

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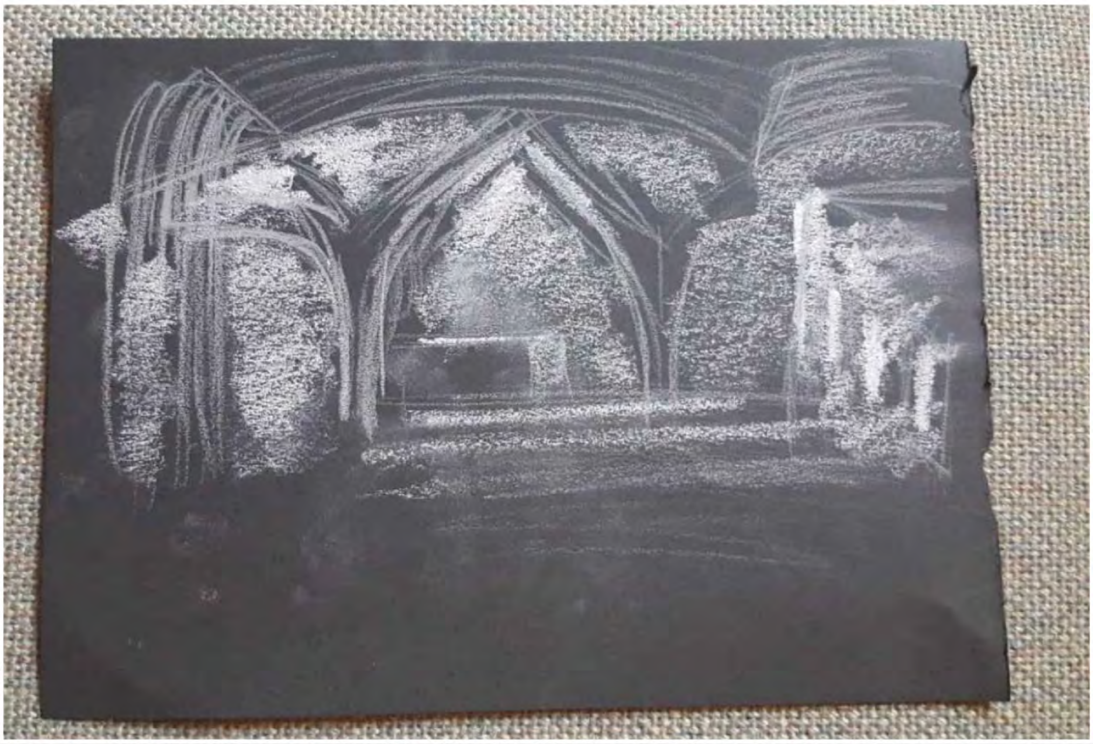
Workshop 2 'Field Visit' – Participant Results



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Workshop 2 'Field Visit' – Participant Results

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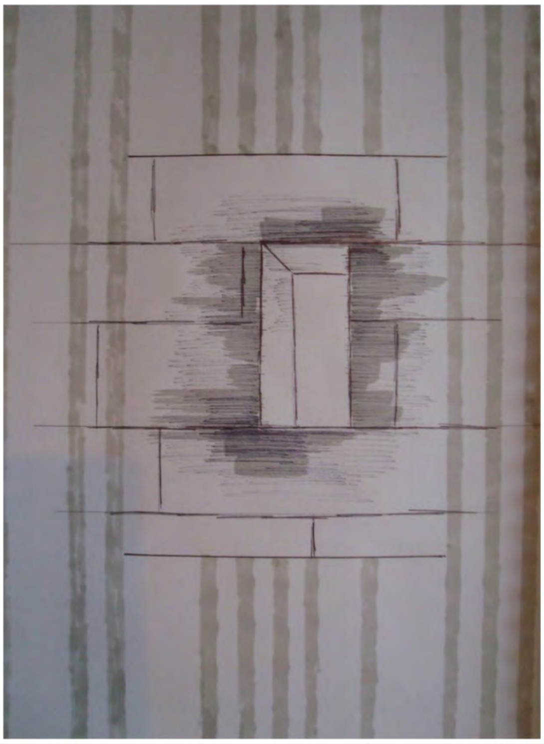

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Workshop 2 'Field Visit' – Participant Results

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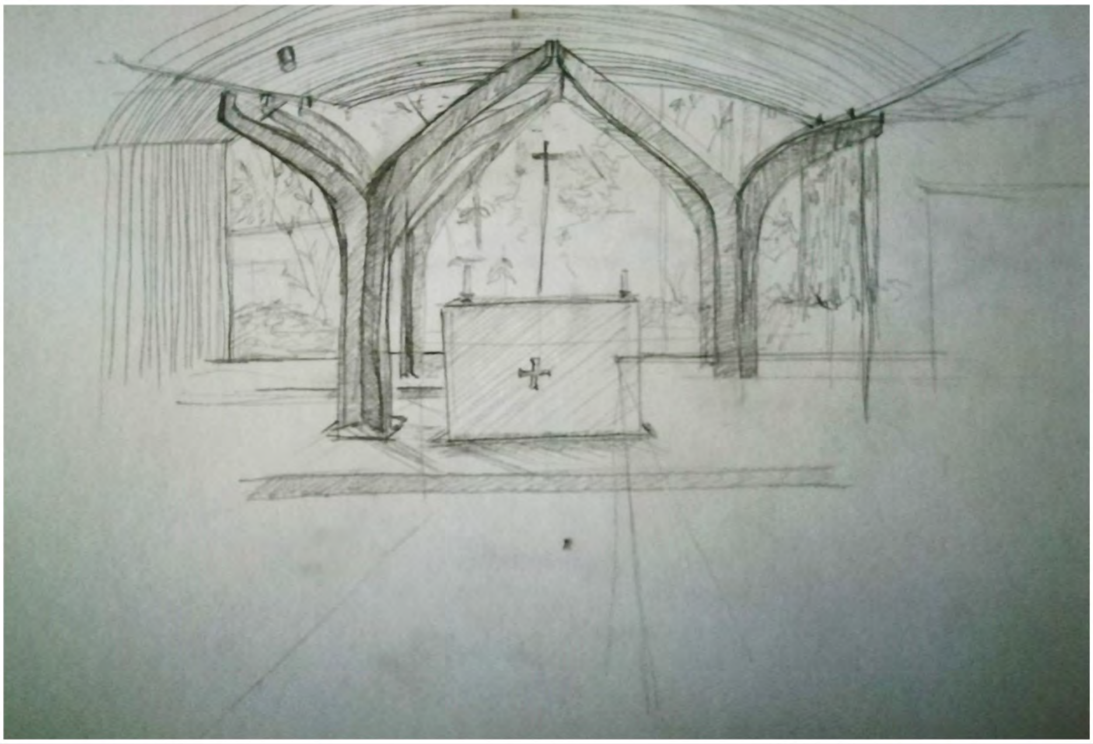
Workshop 2 'Field Visit' – Participant Results



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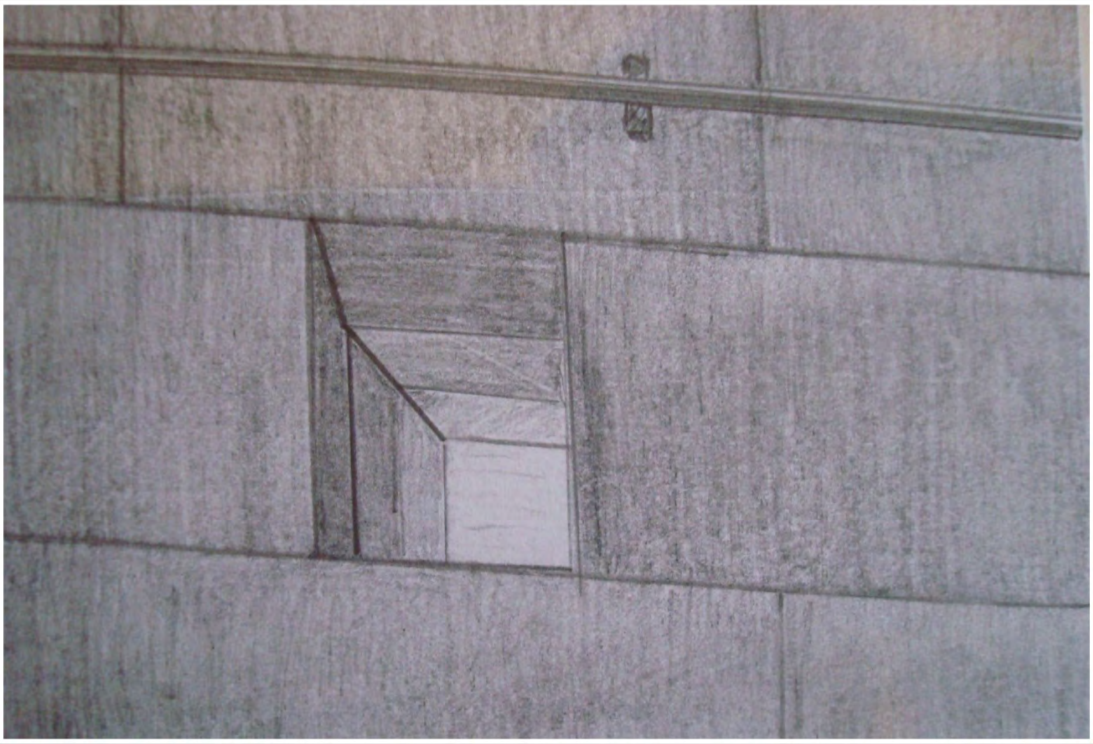

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Workshop 2 'Field Visit' – Participant Results

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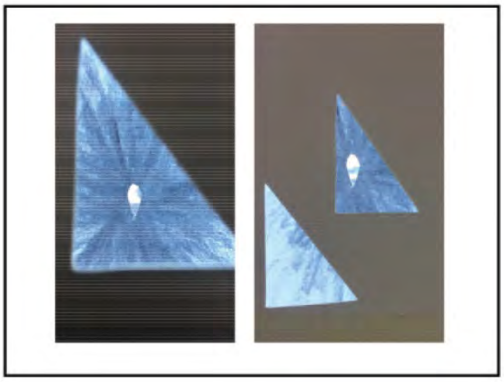
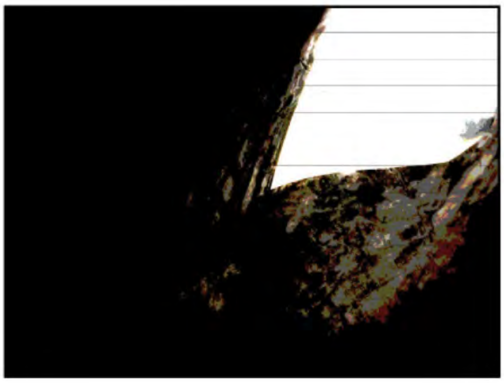
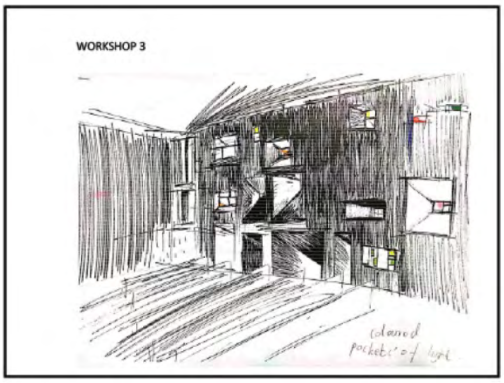
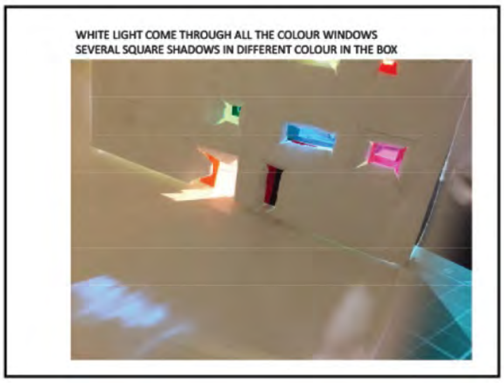
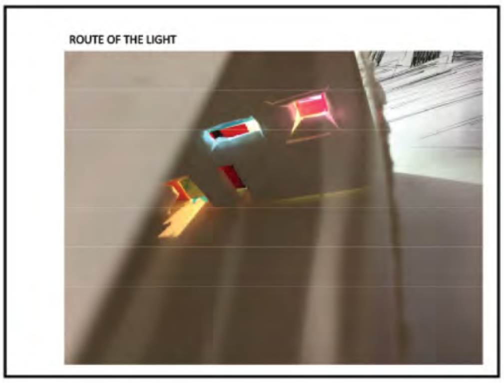
Workshop 2 'Field Visit' – Participant Results



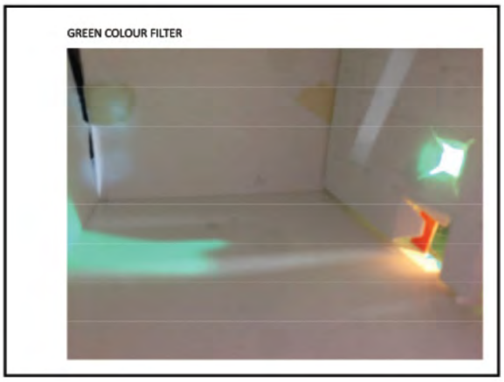


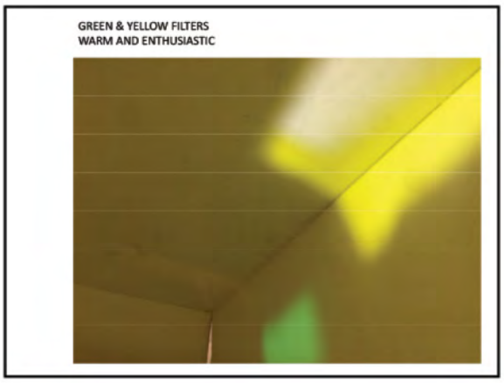


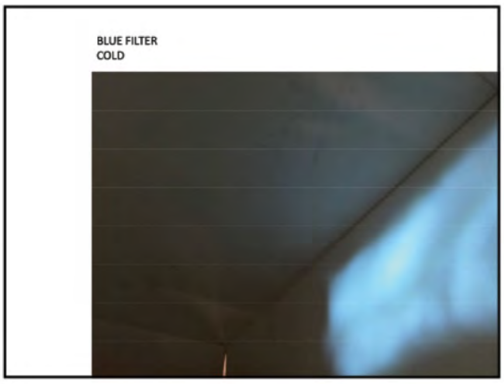




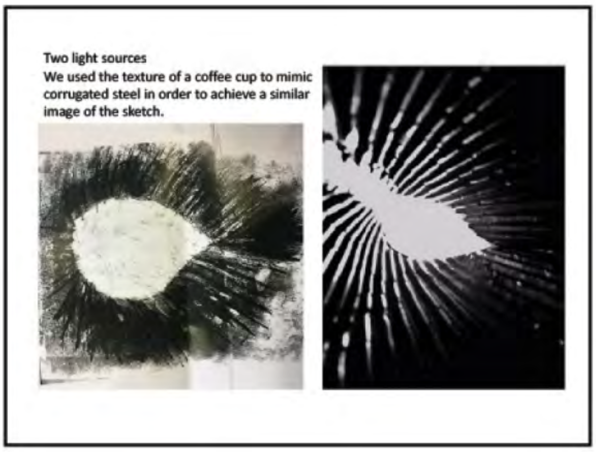
Workshop 3 'Create Model:Studio' Case Study 1 – Participant Results

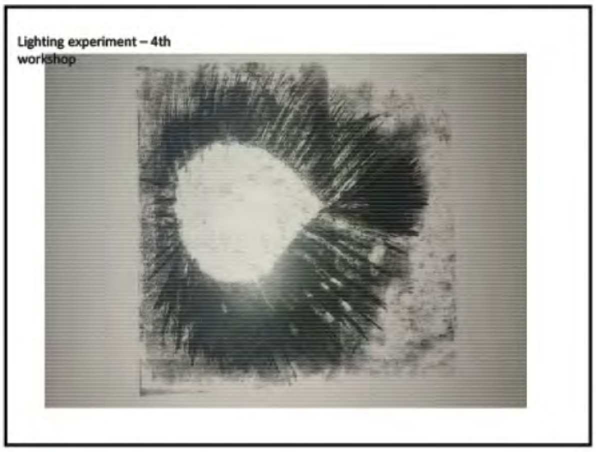


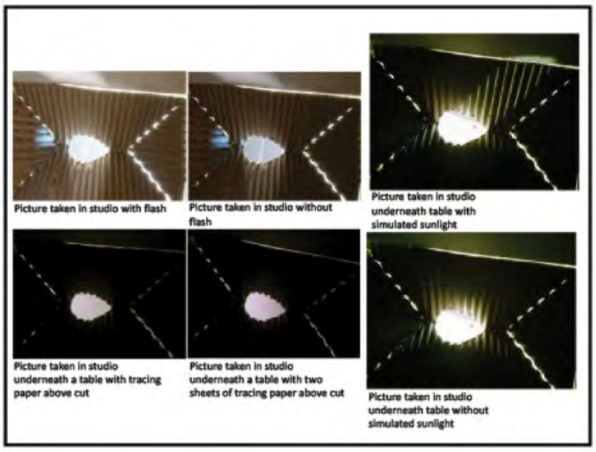


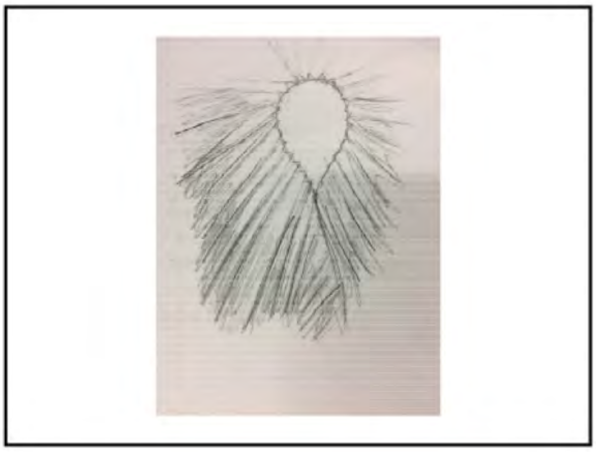


Workshop 3 'Create Model:Studio' Case Study 1 – Participant Results

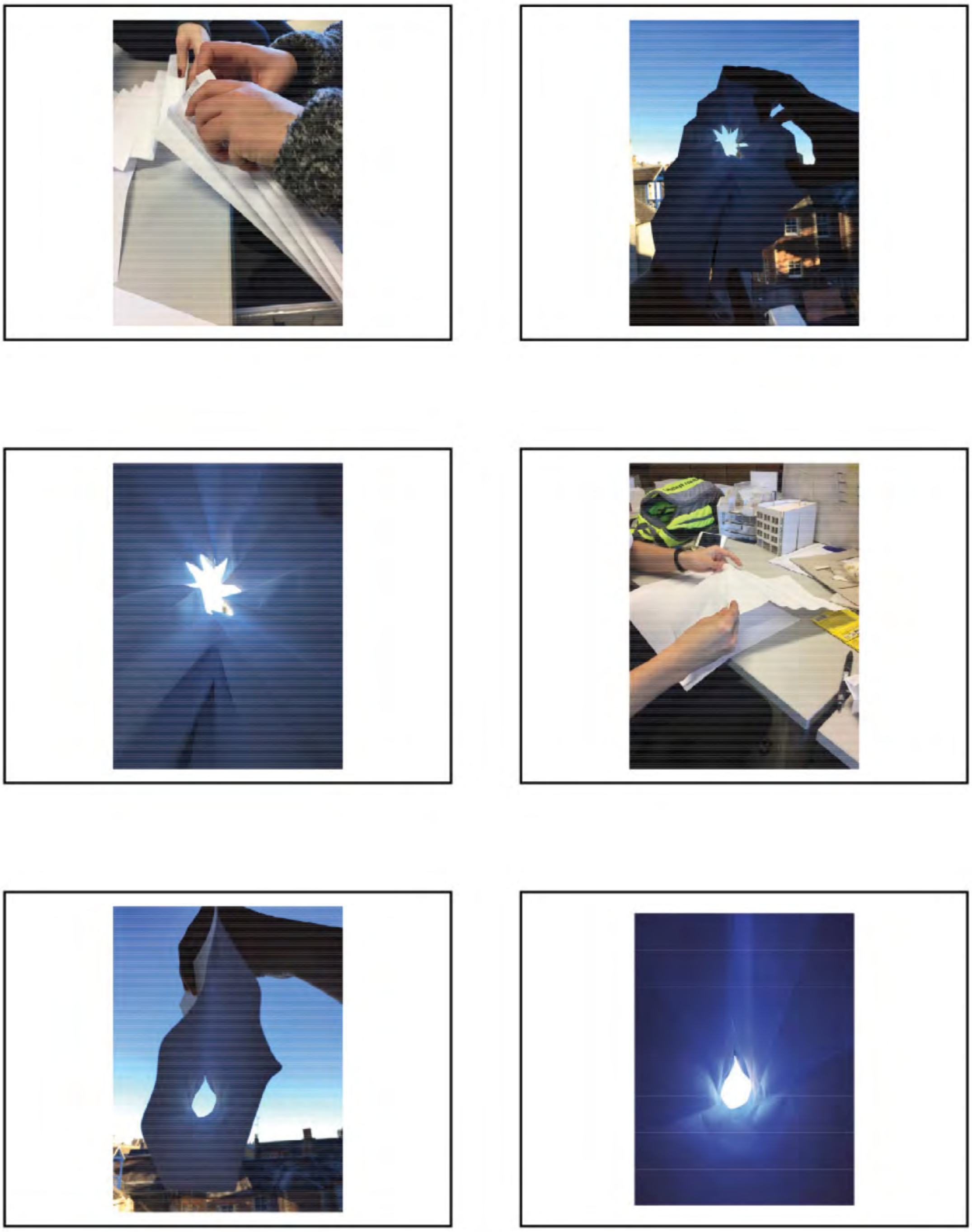






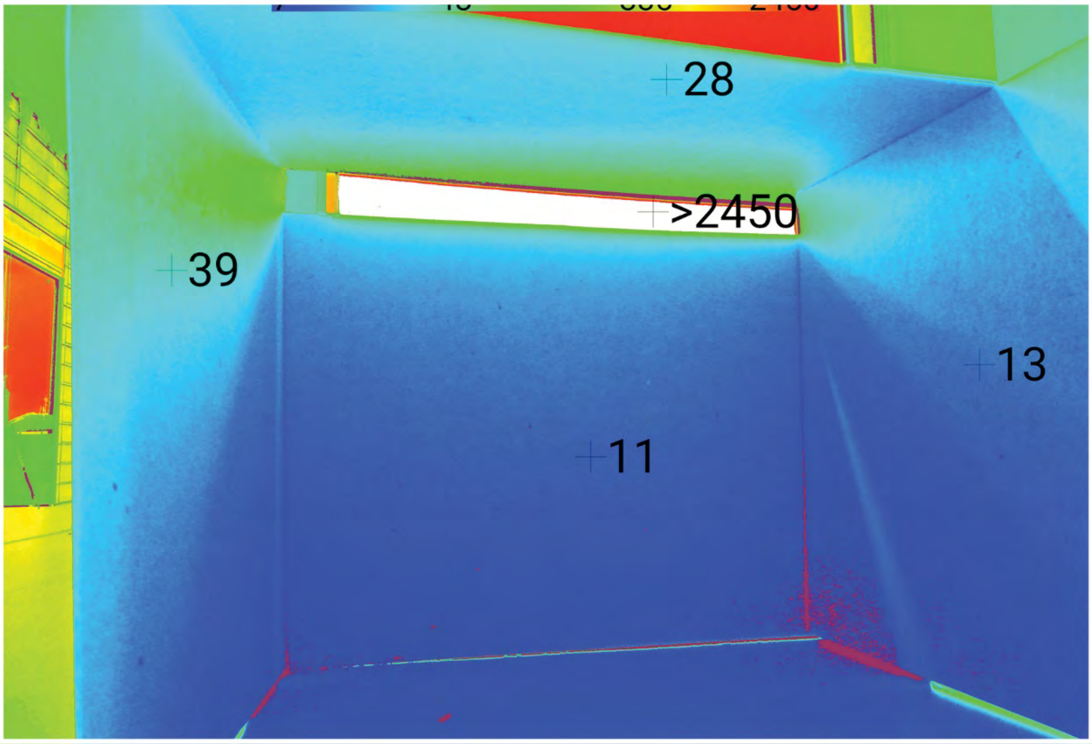


Workshop 3 ‘Create Model:Studio’ Case Study 3 – Participant Results



Workshop 3 'Create Model:Studio' Case Study 3 – Participant Results

A



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Workshop 4 'Model:Studio' Case Study 4 – Participant Results

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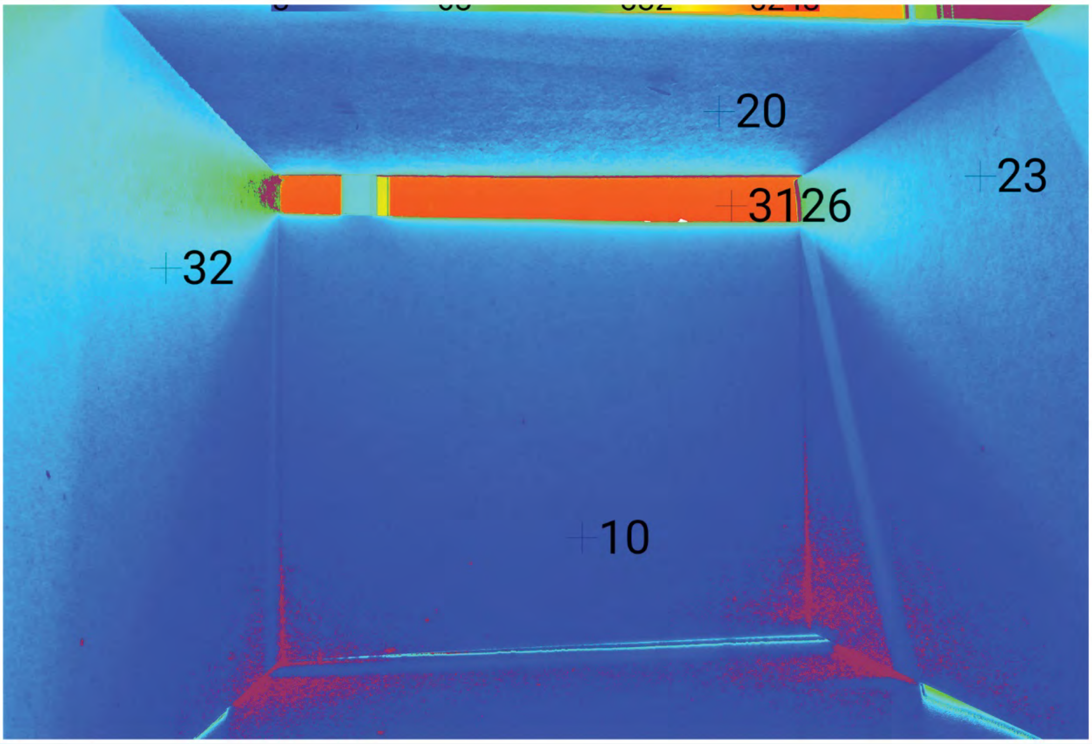

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Workshop 4 'Model:Studio' Case Study 4 – Participant Results

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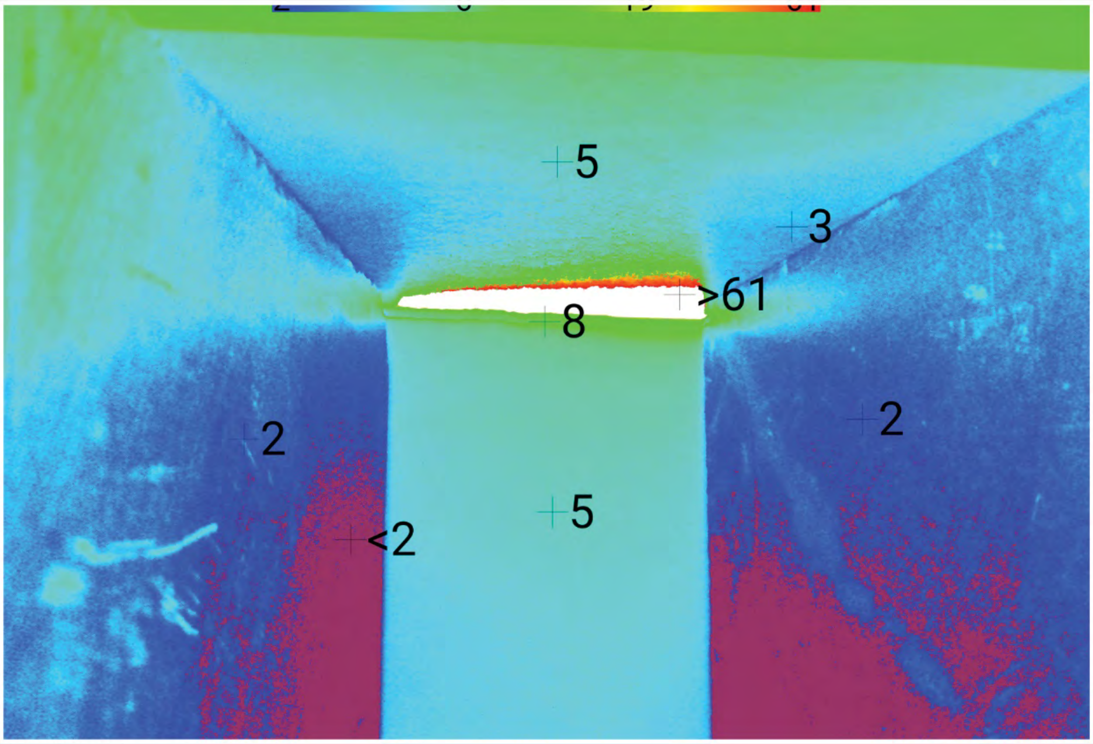

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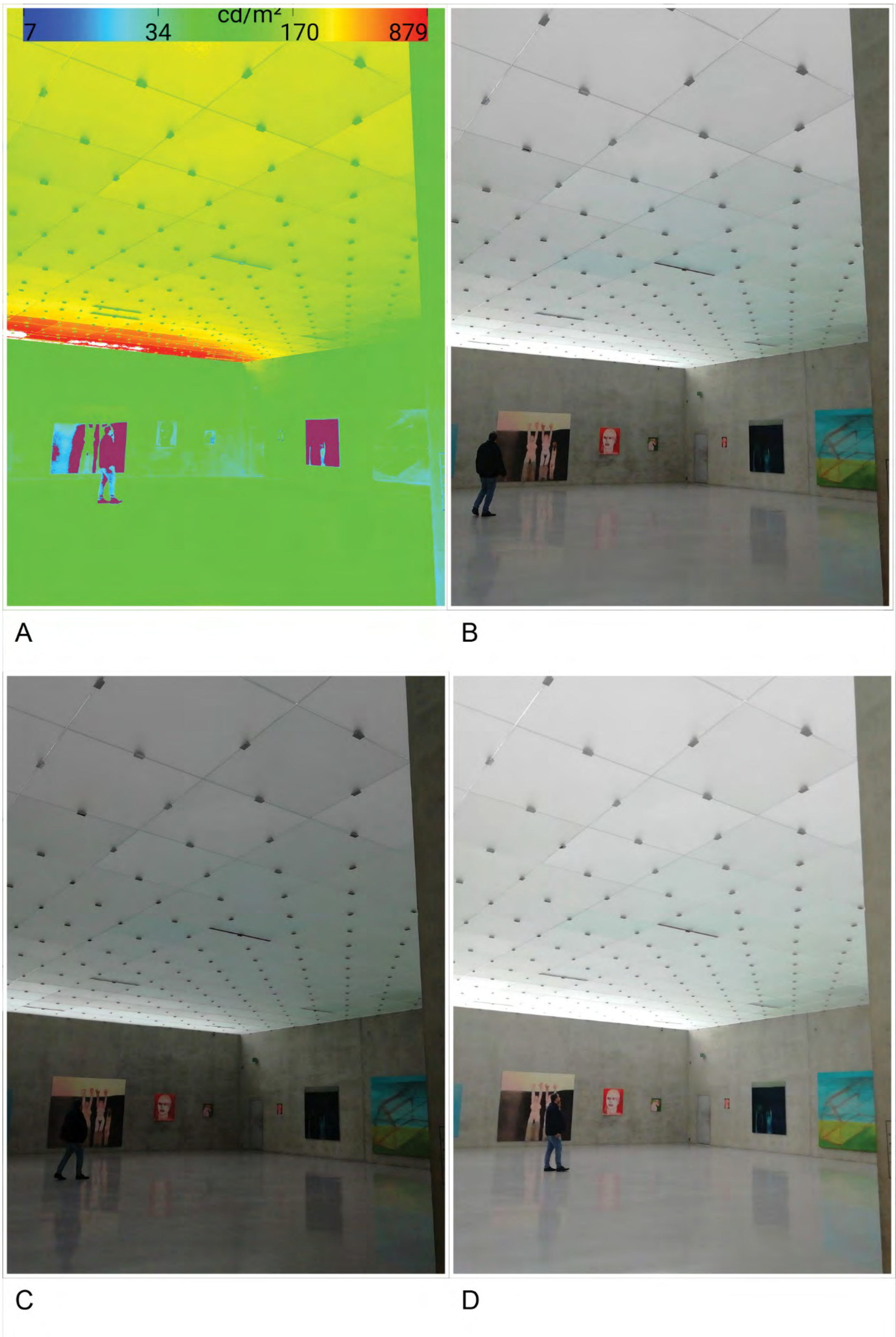
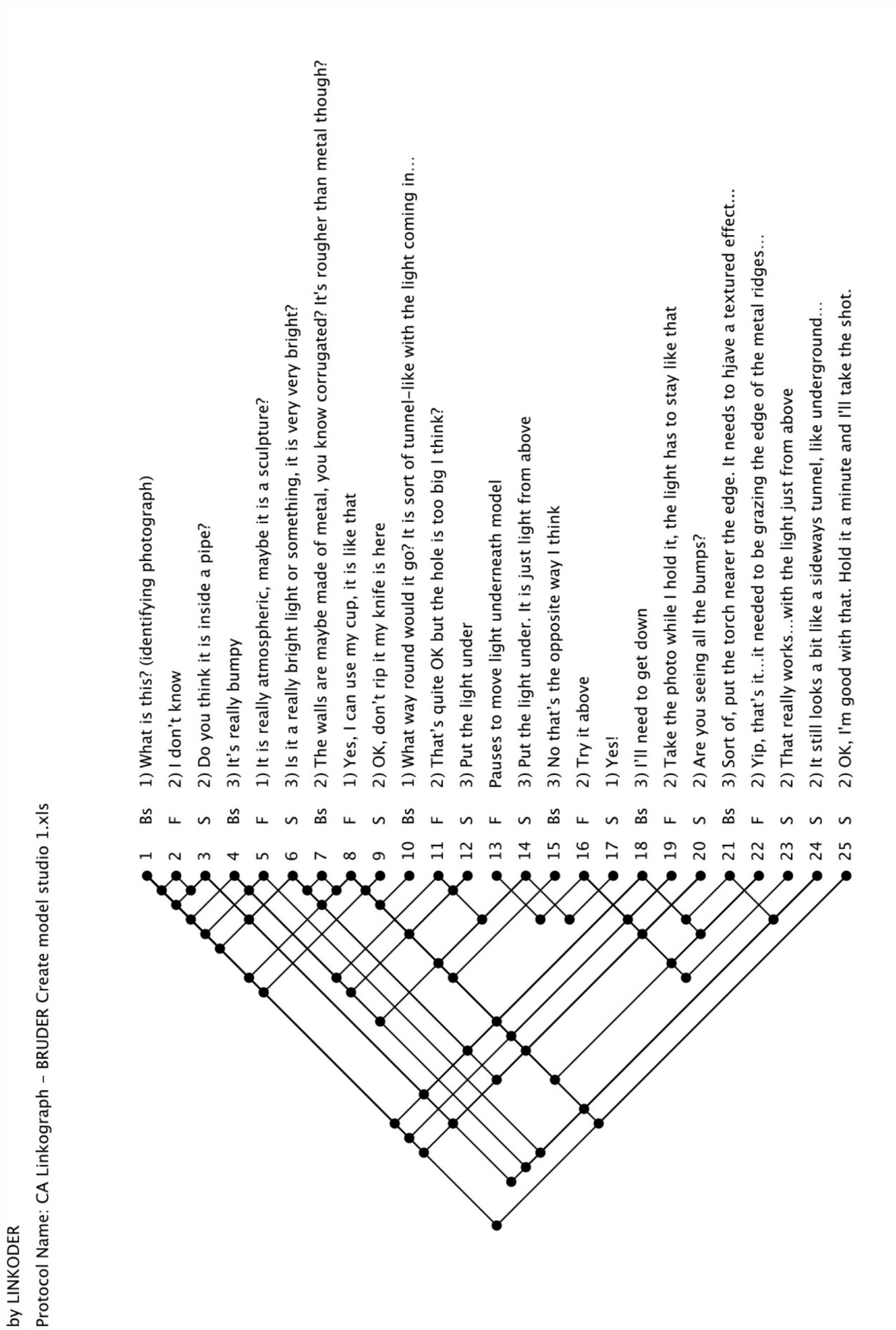
Workshop 4 'Model:Studio' Case Study 4 – Participant Results

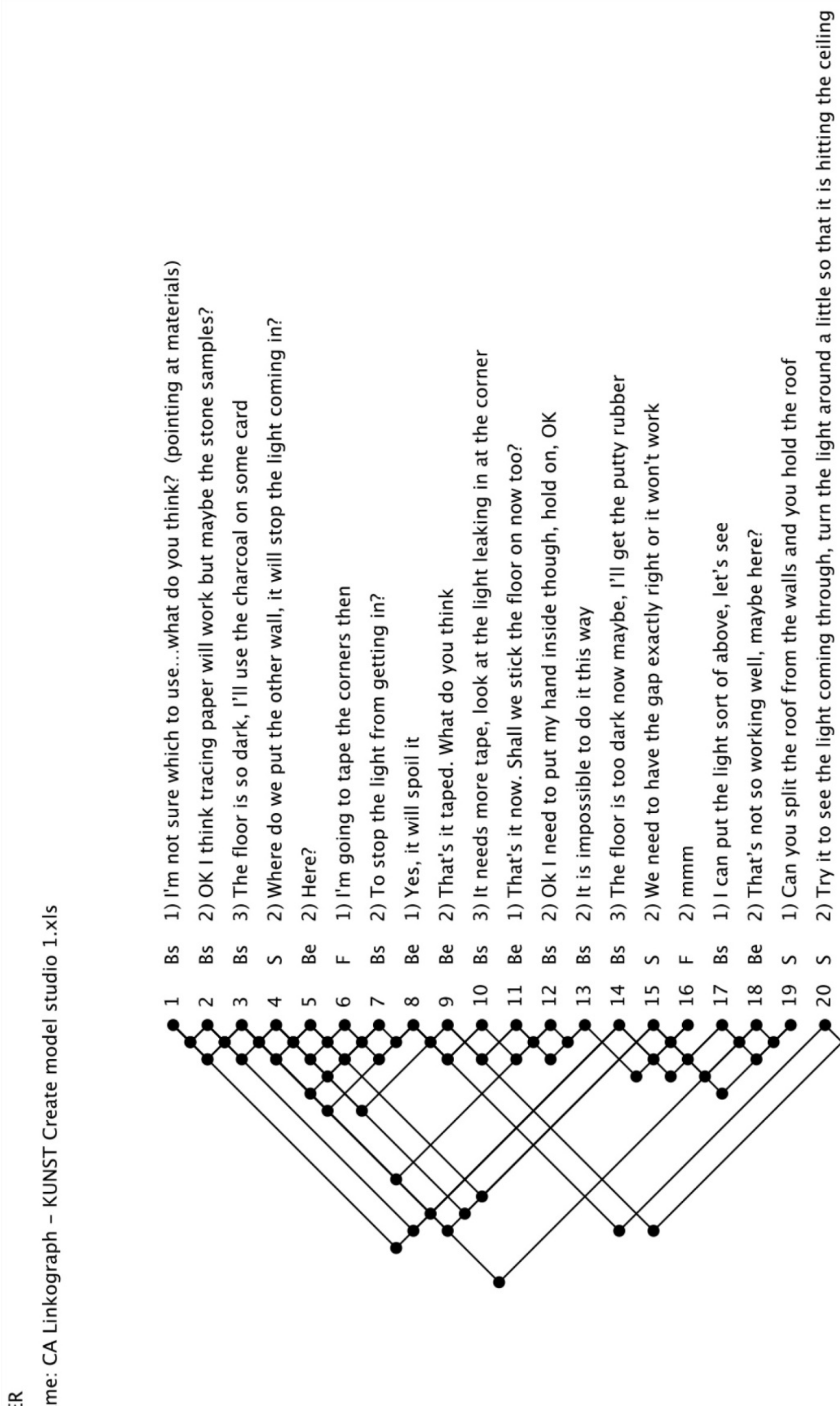


Workshop 4 'Model:Studio' Case Study 4 – Participant Results

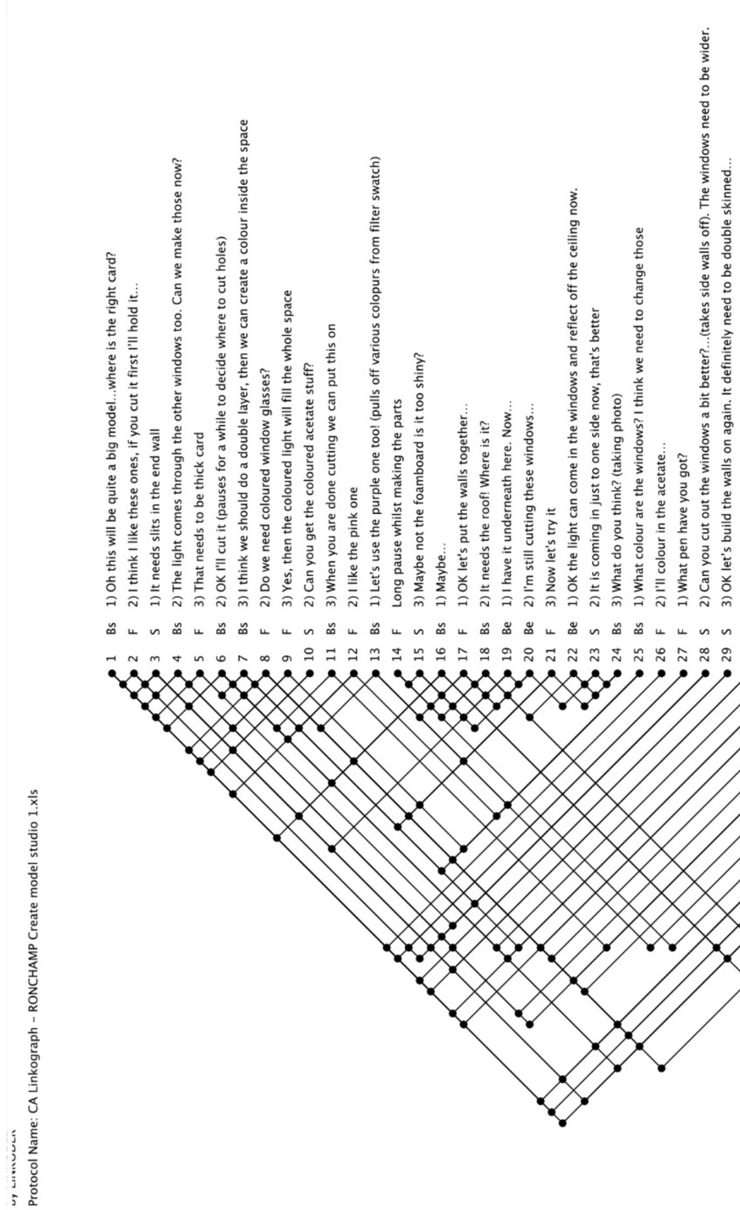
APPENDIX VII Chapter 7: Linkographs and Lexicons



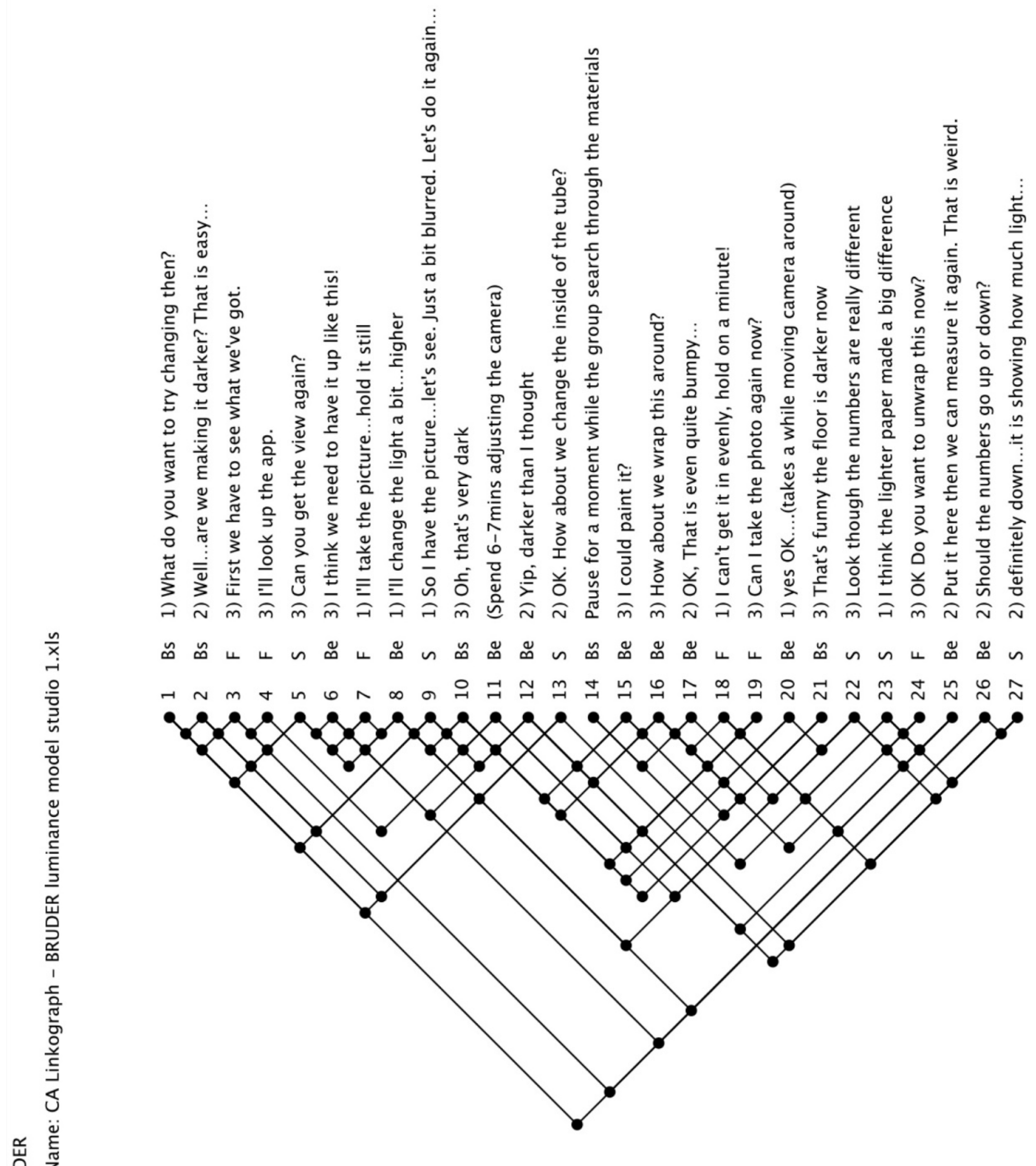
Workshop 3 'Create Model:Studio' Case Study 3 – example Linkograph



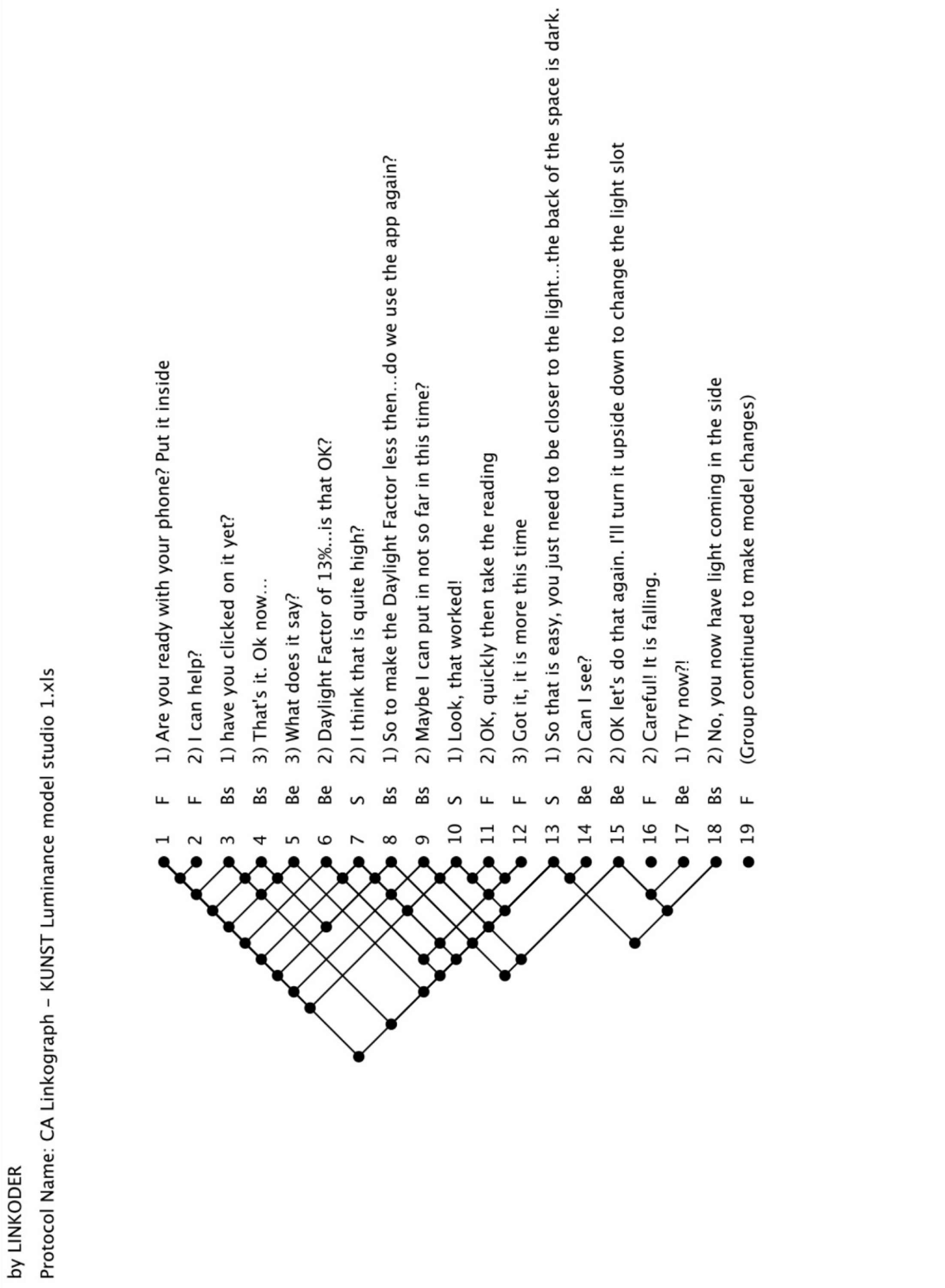
Workshop 3 'Create Model:Studio' Case Study 4 – example Linkograph



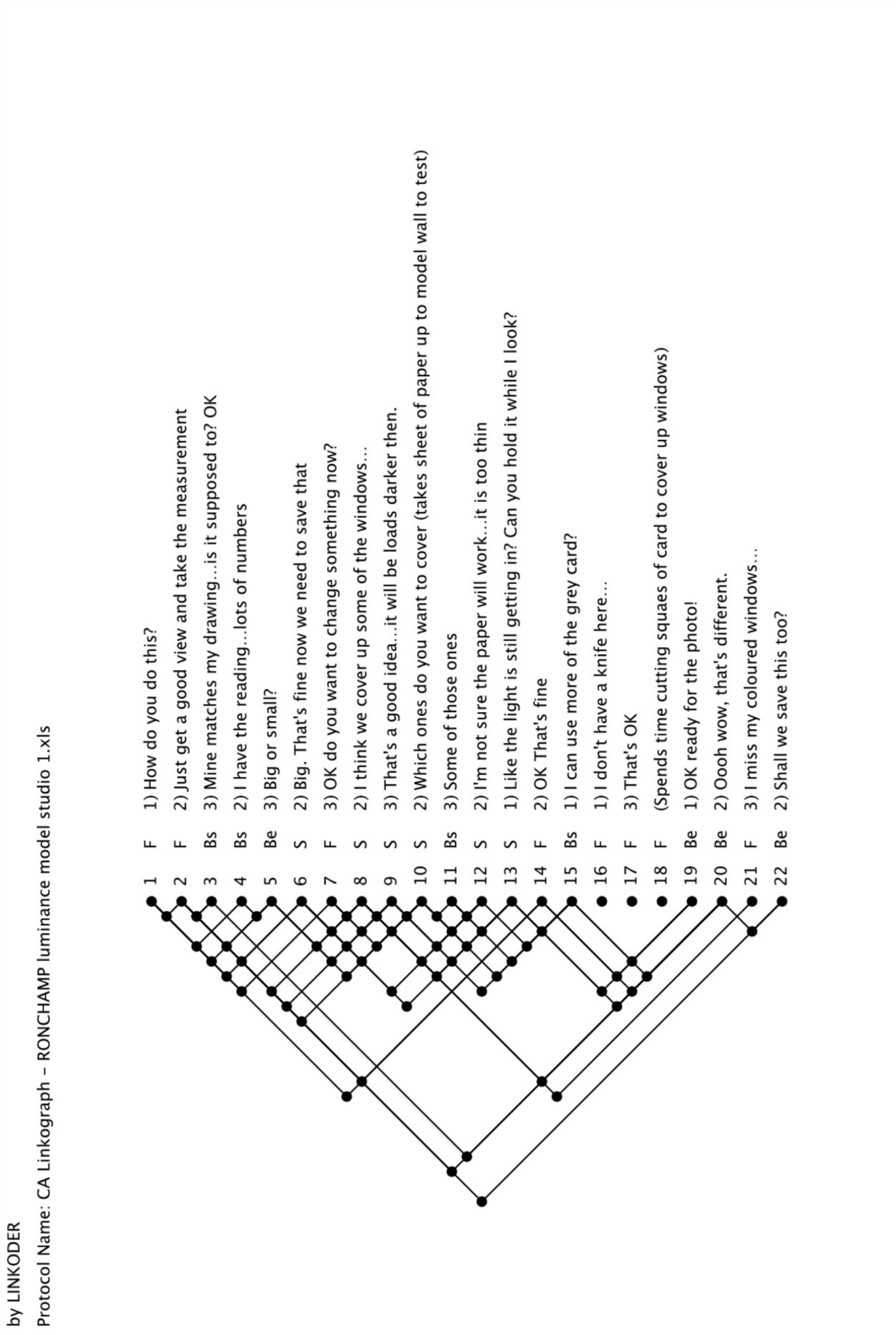
Workshop 3 'Create Model:Studio' Case Study 1 – example Linkograph



Workshop 4 'Model:Studio' Case Study 3 – example Linkograph



Workshop 4 'Model:Studio' Case Study 4 – example Linkograph



Workshop 4 'Model:Studio' Case Study 1 – example Linkograph

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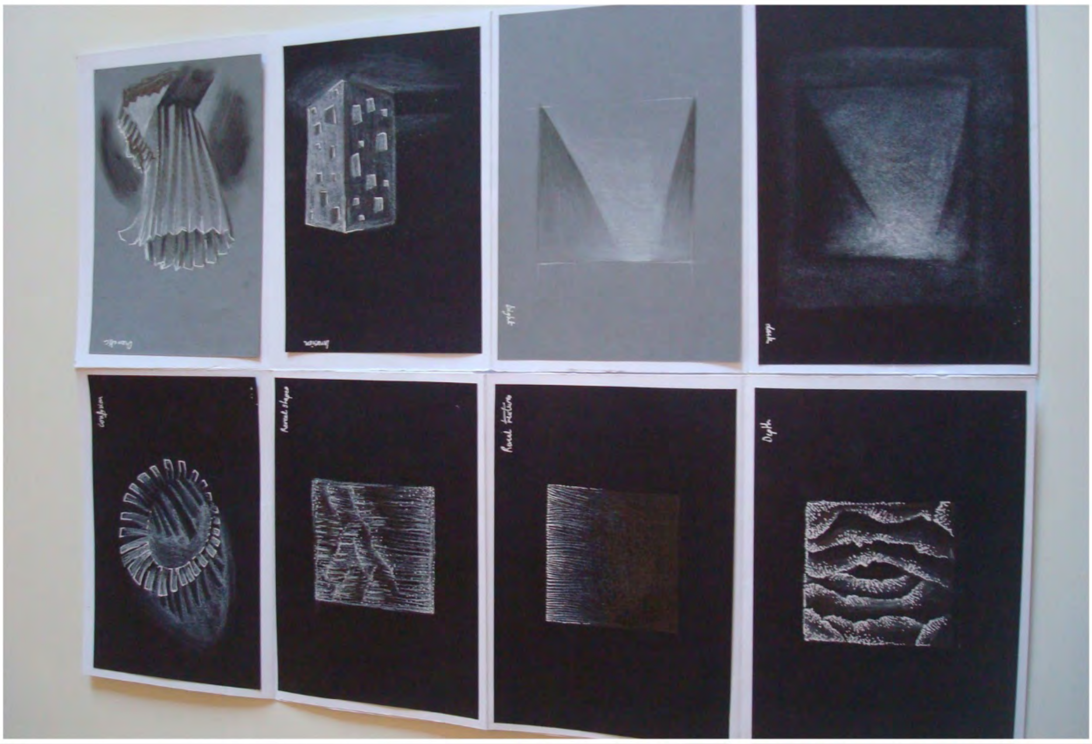

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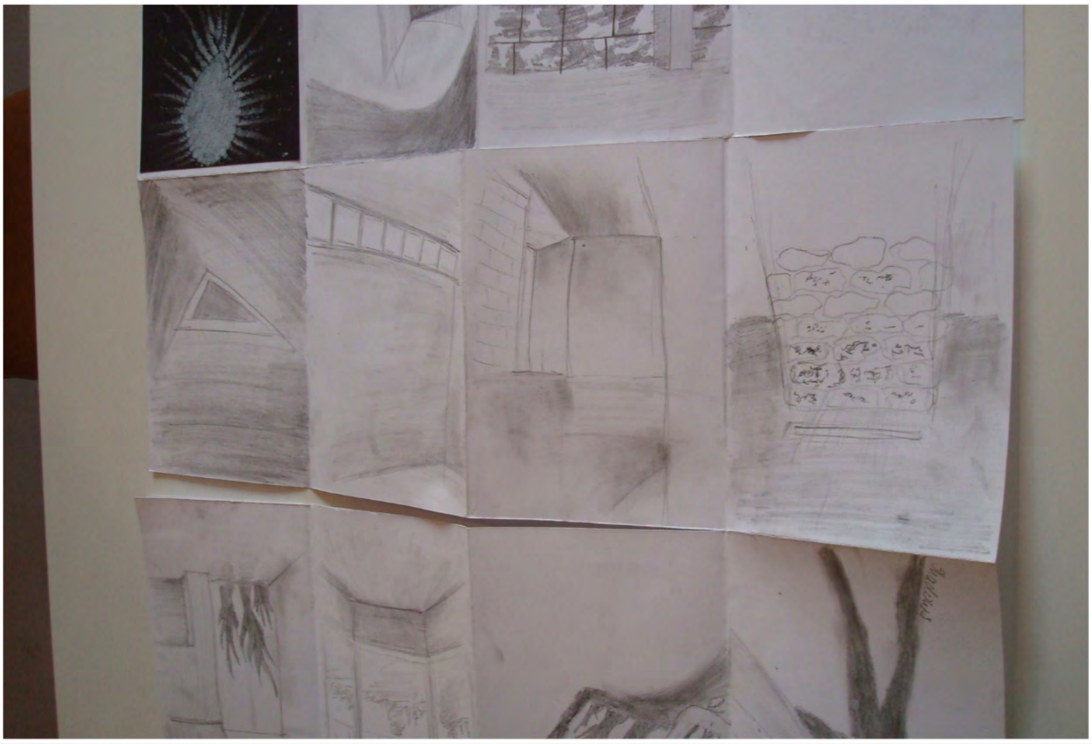
Workshop 6 'Visual Lexicon' – Participant Results



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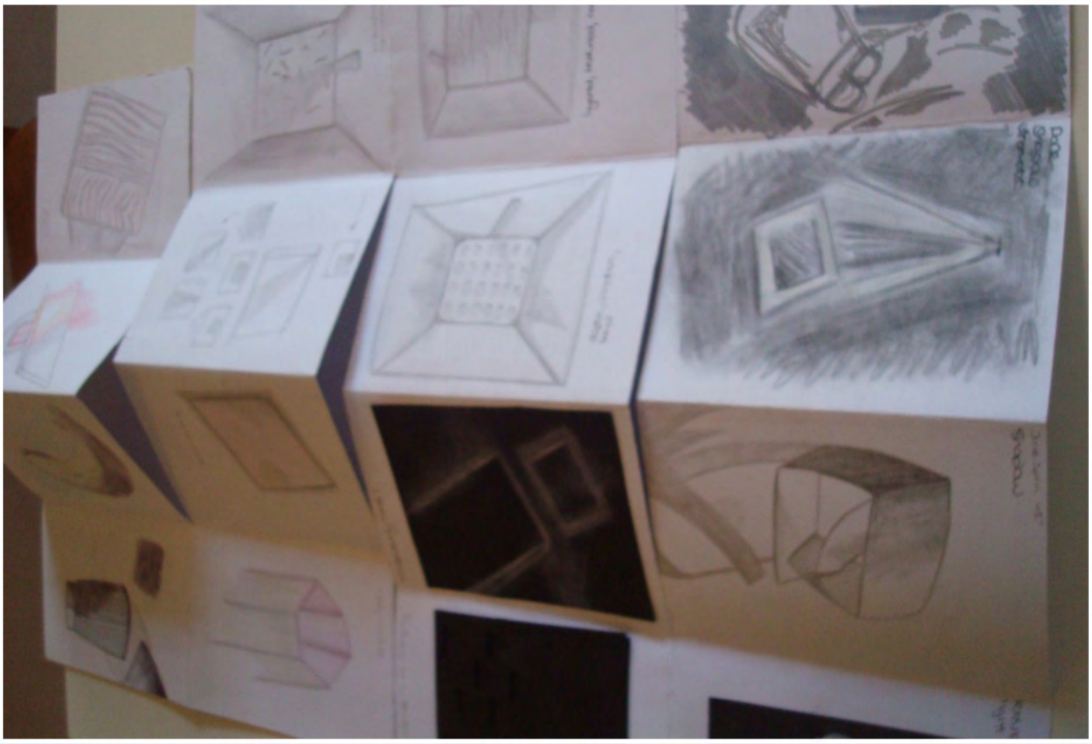

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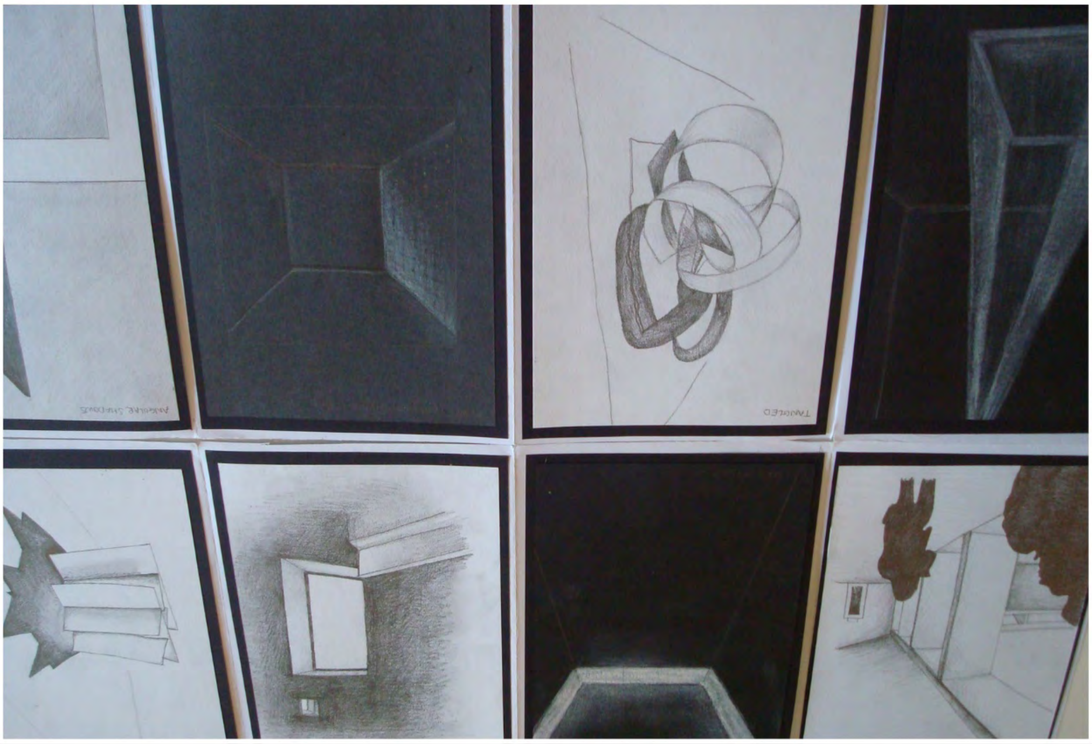
Workshop 6 'Visual Lexicon' – Participant Results



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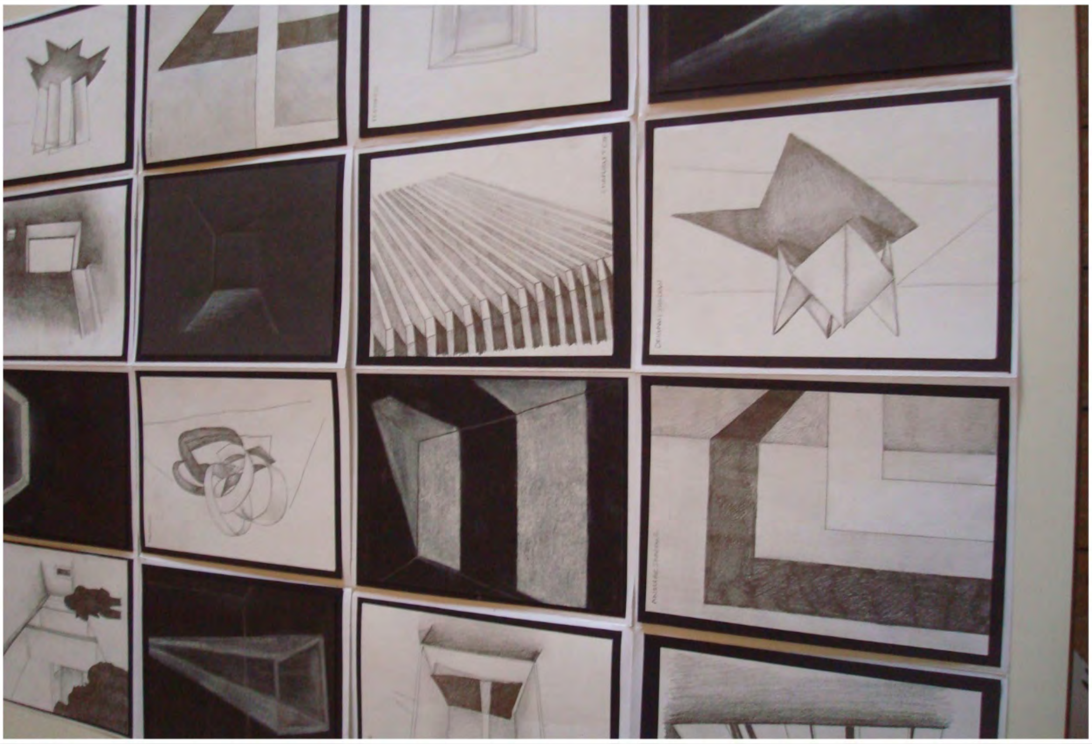

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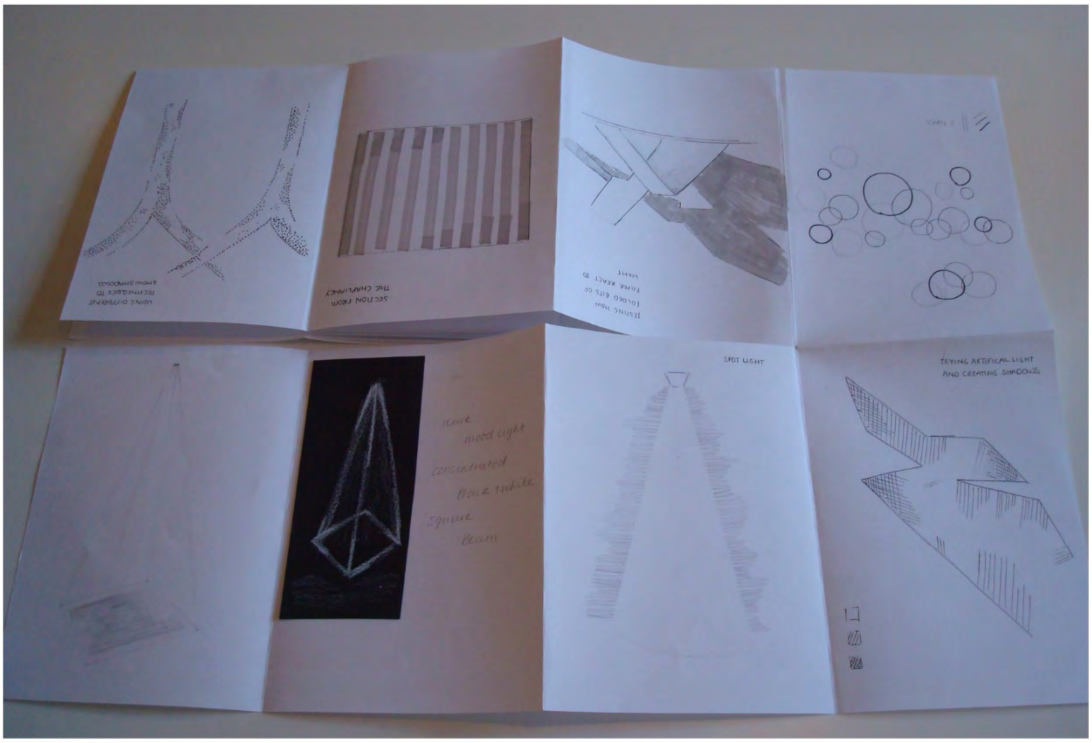
Workshop 6 'Visual Lexicon' – Participant Results



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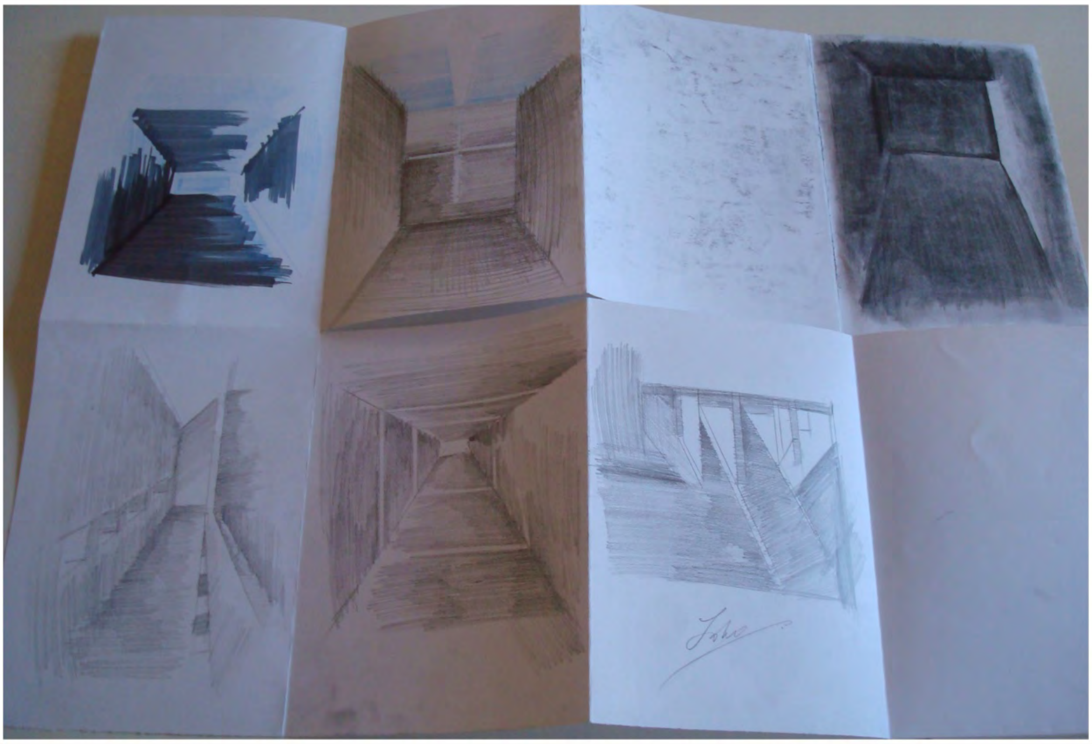

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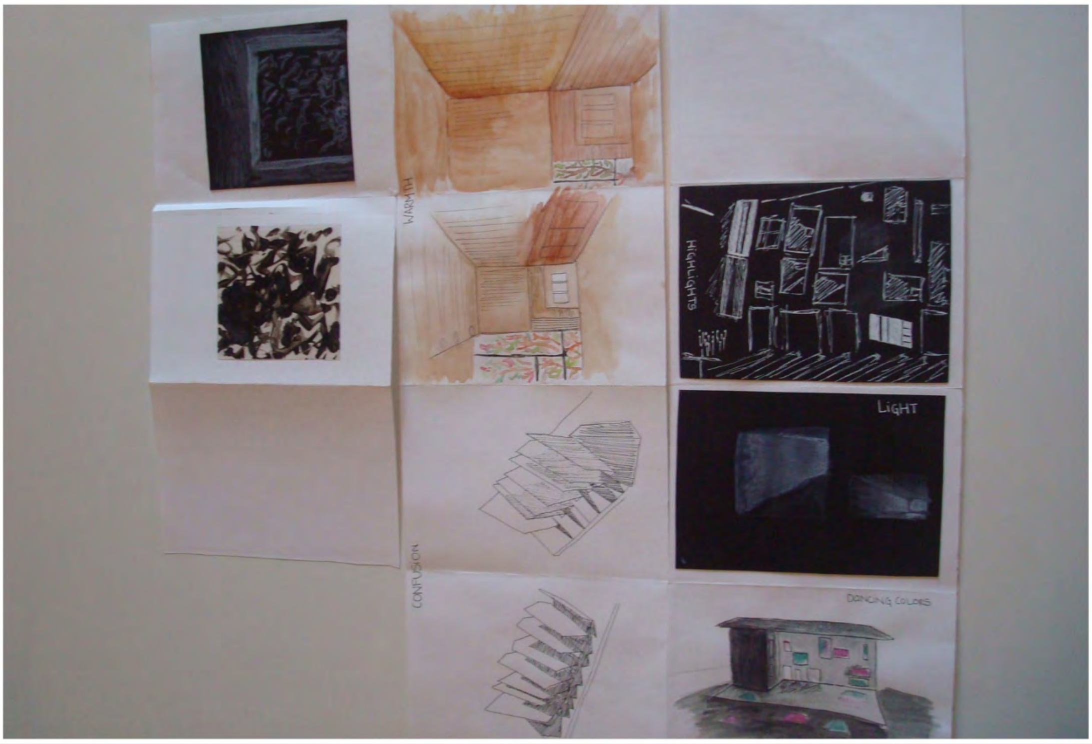
Workshop 6 'Visual Lexicon' – Participant Results



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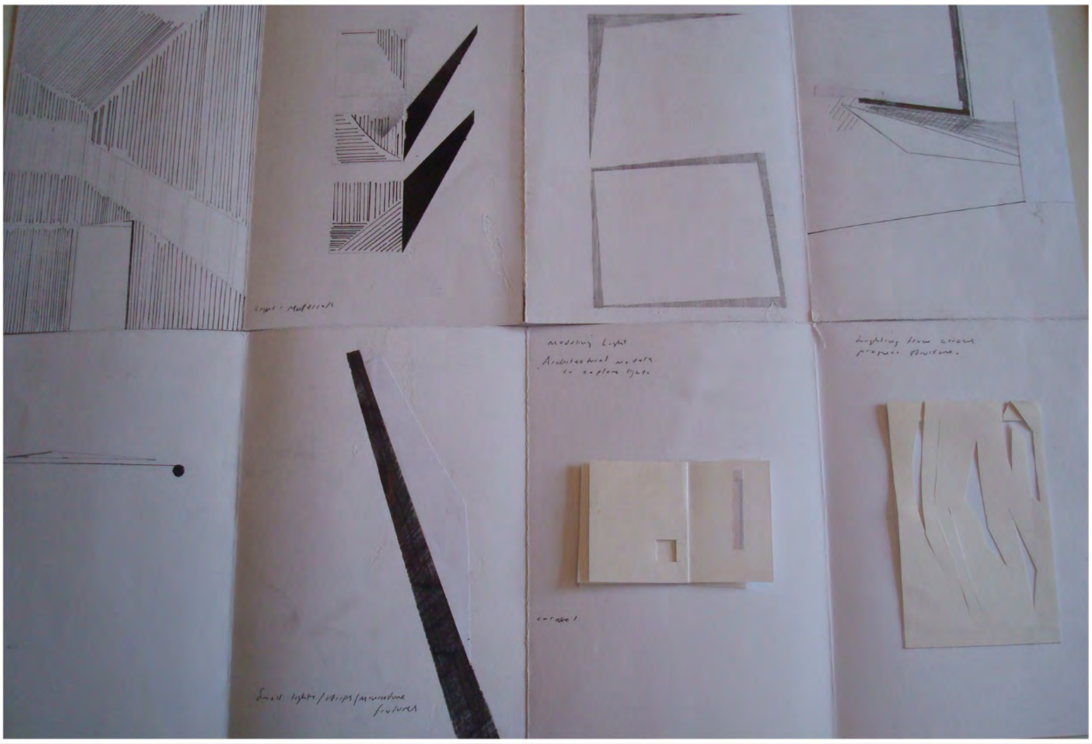

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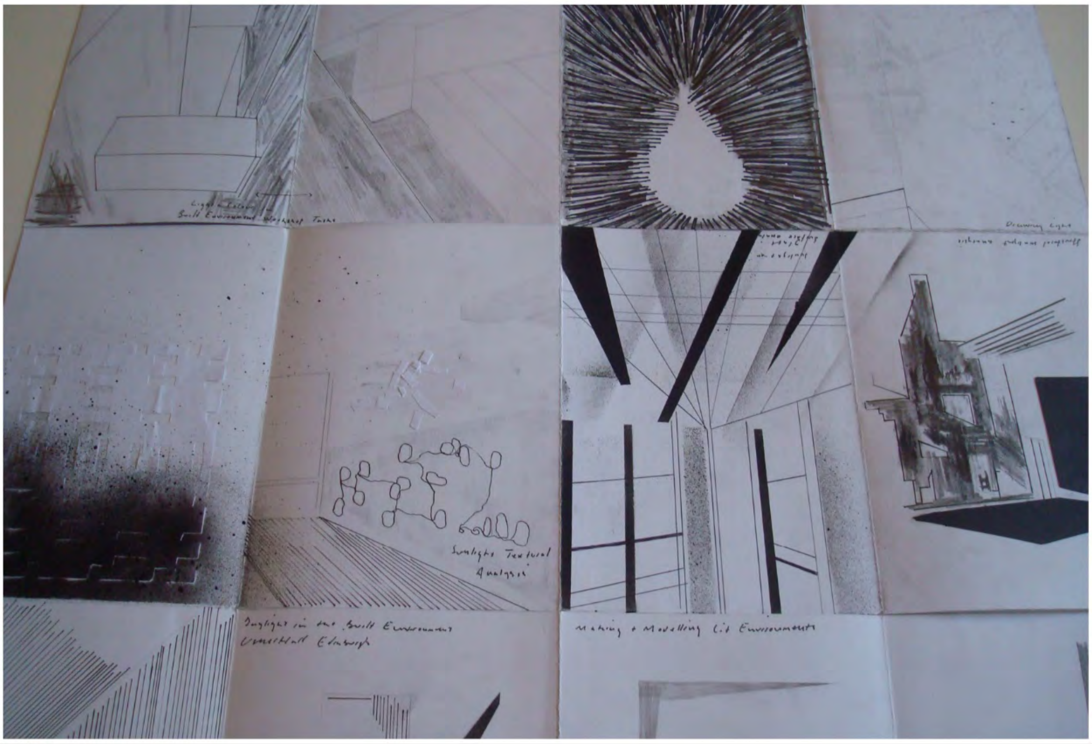
Workshop 6 'Visual Lexicon' – Participant Results



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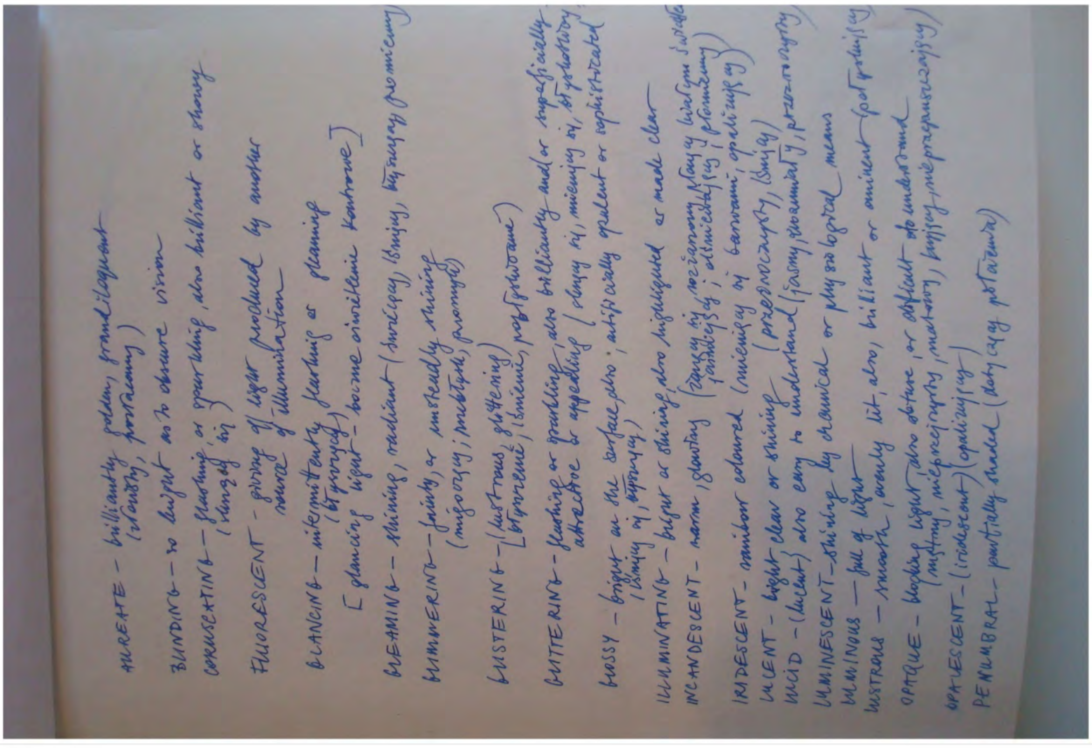

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Workshop 6 'Visual Lexicon' – Participant Results