Practical-Research: integrating research in architectural practice

The use of semi-scientific investigations, such as evaluating building performance by simulations, measurements, and surveys, takes an increasing role in the architectural practice. However, systematic methodology or practical workflow for integrating these investigations into the architectural design process is still missing. As a result, the data produced has a limited effect on the building performance. This research studied the nature of these investigations in relation to academic or applied research; especially in the framework of daylighting research and design. The research suggests that modified methodologies of academic and applied research, systematically integrated into the design process, can help to improve performance. However, since the scope and objectives of such investigations are substantially different, the term *Practical-Research* is proposed. A conceptual model for integrating Practical-Research in the architectural design process is suggested. The model utilizes a comprehensive approach to organize the tasks required for an effective design of expert fields (such as daylighting, solar shading, thermal properties, acoustics, and natural ventilation), according to the design phases and the required expertise: architectural design, expert consultation, and Practical-Research. To illustrate the model and provide a practical tool supporting the daylighting design process, the conceptual model is further developed into a *Daylighting Workflow*.

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Introduction
Traditionally, many of the expert fields, such as daylighting design, are carried out at the architect's desk. In order to achieve quality daylight, the architect uses information from past experience, either his own or of others' (often from books and magazines). The architect often conducts some logical and visual investigations through sketching and very seldom conducts some visual experiments with scale models. In addition, the architect may also utilize information generated through academic research (published in books and standards).

In order to improve building performance, such as quality daylighting, academic research often evaluates different shading and daylighting strategies for their effect on occupants' performance, health, visual and thermal comfort, and energy conservation. The common outcome of such a research consists of performance targets (visual comfort requirements often published as standards) and a prescriptive list of recommended characteristics of shading and daylight systems. However, from the architect's point of view, both performance and prescriptive recommendations have some drawbacks: performance targets do not provide the architect with the means or methodology to meet these goals, whereas the prescriptive recommendations provide solutions only for some architectural and climatic scenarios – but not all.

Recently, there has been an increasing use of simulations to support expert design fields, such as daylighting design. For example, in the daylighting field, simulations are mostly carried out by either architects or consultants (Galasiu & Reinhart, 2008). Since simulation has the potential to make meaningful contributions to daylighting design, it is anticipated that it may be further developed in the near future to enable easier utilization. As a result, the use of such simulations is likely to become more common. However, a methodology (or methodologies) of integrating these simulations within the design process is still missing. In general, the methodologies currently employed are either pure academic research (which does not fit the architectural practice well) or practical methods developed by individual users (which are not available for other users). Several recent attempts to develop such methodologies include the Daylighting Road Map (IEA-SHC, 2005) and the 10-step daylighting design process (Pasini, 2002); however, in general, these are over-simplified, and cannot deal with the required complexity. Recently, several simulation tools were created with the design process in mind, such as Building Design Advisor (BDA) (Papamichael, LaPorta, & Chauvet, 1997; The University of California, 2006), Ecotect (Marsh, 2004), the Virtual Lighting Laboratory (VLL) (Inanici, 2003), Daylight 1-2-3 (Reinhart et al., 2007), Sensor Placement & Optimization Tool (SPOT) (Architectural Energy Corporation, 2006), Daysim (Reinhart, 2012), Lightsolve (Andersen, Kleindienst, & Gagne, 2010), and the daylighting Dashboard (Reinhart & Wienold, 2011); however, these developments were focused mainly on the development of the computer program itself.

Without a coherent methodology of integrating tools for performance evaluation, such as daylight simulations, within the design process, their contribution is likely to be small: without asking the relevant design questions, at the correct design step, and without having means of ensuring a successful integration of the outcome of these tools in the design, they often become useless. Therefore, the primary objective of the research was to develop methodologies for research in architectural practice; supporting various expert fields of design, especially the design of daylighting for visual comfort and energy conservation in offices.

Methodology

In order to support the development of research methods for architectural practice, the research included meta-analysis of academic daylighting research, a field survey of offices and controlled daylighting experiment, carried out in the framework of the first part of the author Ph.D. research {{392 Author 2012;}} and syntheses with several aspects of daylighting practice.

The meta-analysis included additional analyses (beyond the conventional analysis of academic research), in particular analysis of the research methodology employed in the daylighting research and analysis for revealing tacit information. The process of the daylighting research was used as a case study representative of academic research methodologies in general. The underlying assumption of this approach was that academic research methodologies, with some modifications, may also be used as a solid foundation for research in architectural practice. The analysis also searched for tacit information existing especially within the research layout. This approach assumes that prior professional knowledge was used to select the research inquiries and process (before initiating the survey); after the survey completion, with the benefit of knowing the results, it is possible to extract this tacit information.

The meta-analysis of the offices survey consists of: Inquiries Analysis, used for identifying the most important data inquiries and for revealing tacit information; Process Analysis, used for evaluating the research process in regard to the research objectives and results; and

Results Analysis, used for identifying the typical structure of the surveys' results. The meta-analysis of the controlled daylighting experiment consists of: evaluating the suitability of the research process for practical-research, and investigating methods of identifying meaningful correlations.

The syntheses were designed to bridge the knowledge gap between the focused knowledge acquired through the academic study of daylighting in offices in sunny locations and the comprehensive knowledge required for the development of a workflow for conducting daylighting design and research in architectural practice. The syntheses consisted of first expanding the literature review of various fields, which the research sub-problems interface. The syntheses dealt with the following topics: merging processes of academic research and design practice; addressing the unique features of the architectural design process; addressing the architectural cognitive processes; accounting for meta engineering concepts; addressing a comprehensive approach for daylighting; mapping design problems, daylight solutions, and research methods; better defining Practical-Research questions; accommodating daylight metrics and standards; addressing computer simulations and design optimization; and applying Systematic Innovative Thinking (SIT).

The focused knowledge acquired through the fundamental daylight research and its meta-analysis and comprehensive information from the syntheses were merged to generate Practical-Research methods and models, which were finally compiled into a proposed daylighting workflow, through a number of flowcharts and several models.

Key insights from the analysis

The research analysis, both meta-analysis and synthesis, produce numerous insights {{392 Author 2012;}}, key relevant insights are presented below. The meta-analysis of the controlled experiment on daylighting consisted of assessing the suitability of the academic research process for research in architectural practice, too. It was found that the key steps and their order are similar; however there is a considerable difference between the two realms (academic and practice), especially regarding the objectives and scope of most steps. An important contribution of the syntheses is identifying tasks of carrying out daylight simulations and post occupancy evaluation, as a systematic inquiry or investigation, which has many of the characteristics of research, rather than a traditional design task. Nevertheless, this process is not quite the same as an academic or an applied research process.

The syntheses generated numerous insights. Among these, the first synthesis, which included analysis of a case study for research in the architectural practice, showed that in practice, continuous consulting is essential to ensure the implementation of research results, which might otherwise be lost during the design and construction process. The initial hypothesis suggested that it would be possible to develop a Practical-Research methodology, which encompasses a holistic approach and deals with all relevant design issues, to ensure that the research outcome would be implemented. However, it was found, through the meta-analysis and synthesis, that the research process (even in architectural practice) has to be focused, and therefore cannot be expanded to solve comprehensive problems. At the same time, it was observed that if the solution is not comprehensive, the likelihood that the outcome of the Practical-Research would be successfully implemented in the project is very low. Among other problems, the research recommendations would most likely be lost during the design process. To overcome this problem, an additional process is required - a consulting process. This process deals with the sub-problems of quickly and accurately identifying the most important daylighting design problems, the potential solutions, and their implications, as well as inspecting the implementation of the recommendations. All of these have a comprehensive nature, and therefore benefit from a holistic process.

A new approach to research in architectural practice

The research findings of the meta-analysis and the synthesis led to a new definition of research in architectural practice -- *Practical-Research*, a typical Practical-Research process, a conceptual model for integrating Practical-Research in the architectural design process, and a specific example for such a model -- a daylighting workflow.

Practical-Research: a new term for research in architectural practice

Since on the one hand, systematic inquiry or investigation (such as carrying out daylight simulations and post occupancy evaluation) carried out to support architectural design has many of the characteristics of research (rather than a traditional design task); and on the other hand, such a process is not quite the same as an academic or an applied research processes, a new term is proposed for research conducted in architectural practice -- *Practical-Research*.

Practical-Research is a part of a design and consulting process which emphasizes systematic inquiry and which utilizes research methodologies. It resembles applied research; however its objective and scope are significantly different: While applied research often serves diverse audiences - for example in developing products, guidelines, and standards - Practical-Research often targets only a specific building project: improving its performance, validating compliance with standards, or generating unique solutions. Accordingly, the scope of Practical-Research is usually considerably narrower than the scope of applied research.

The term Practical-Research is already used as part of the book title “Practical-Research: Planning and Design” (Leedy, 1997); however this book discuses research with a much broader scope than that proposed in Author (2012) and this paper. The term Practical-Research describes a research category, referred to also by the terms “Research by Design” or “Practice-Base/Led Research” (Dunin-Woyseth & Nilsson, 2012). The scope of these terms is quite broad and not well-defined. In contrast to the common term Design Research, which usually refers to scientific research into the design process (Cross, 1999), “Research by Design” and “Practice-Base/Led Research” refer to research which creates (or is even a product of) design. In general, the term Practical-Research has a narrower scope (than these terms), since it is designed to support a particular project, rather than the entire architectural field of knowledge, although (in contrast to these terms) it may also include research that is not focused purely upon design.

Finally, a clear definition of Practical-Research may contribute in understanding (and structure) the recent paradigm in architecture, described as “performance-oriented design” (Hensel, 2012) or Performalism (Grobman & Neuman, 2011). The following definition is suggested: *Practical-Research is a systematic inquiry designed to generate missing valuable information to the design team, to improve a particular project*. *It usually consists of a very short autonomous process carried out during certain stages of the design process*.

A typical practical-research process

The proposed process for *Practical-Research* is a modified version of academic or applied research methodologies designed to accommodate the architectural practice. In fact, the suggested steps and their order are fairly similar to a process of applied or academic research (see Figure 1). However, the scope and objectives of most of the Practical-Research steps differ substantially from those of applied or academic research.

On the one hand, founding the Practical-Research methodologies based on academic or applied research methodologies provides a solid and well-structured process for carrying out such investigations in architectural practice as well. On the other hand, since academic or applied research has substantially different scope and objectives than Practical-Research, proposed modifications in the process steps ensure successful outcome in architectural practice, too. An overview of the Practical-Research steps is provided below.

Since Practical-Research requires fitting the architectural practice, the modifications are of a very practical nature.

Receiving Inquiry: In order to initiate Practical-Research, an inquiry is needed. The inquiry can be presented by the consultant, the architect, other design team members, or the client. In addition it can be presented during any phase of the design process, and can be specific or general, clear or vague, simple or complicated. Furthermore, the inquiry may also be presented as a general call for assistance, such as “Can you contribute to the project?”. Since Practical-Research is still uncommon, it might be necessary to approach the design team members, introducing them to the importance of performance investigation.

Defining Problem/s and Stating Objective/s: In contrast to an academic research which investigates fundamental problems (to improve the public knowledge, by advancing the state-of-the-art), Practical-Research aims to solve a specific problem of improving a particular project. The time and budget which are usually available for solving problems in practice are very limited. Therefore it is important to quickly identify the most important problem/s, potential solution/s, and their general implications (such as performance, cost, structure, operation, aesthetics, etc.). Subdividing the problem into manageable sub-problems (research questions) can greatly help in setting up a detailed research plan. Sub-problems are often related to design variables relevant to the expert field (such as daylighting). Stating the objectives after defining the problems can help to explain the research aims; while stating the objectives before defining the problems, can help with identifying problems. For example, if problems are not clear, having a clear objective (such as having sufficient daylight in a specific location) may help defining problems. This may be carried out by introducing the question “what are the obstacles of achieving this objective?”.

Reviewing Literature and Stating Hypothesis: While a literature review is required in academic research to ensure that similar research has not been done before, in Practical-Research a literature review is not required *per se*. Still, a short literature review may be needed in order to better understand the problem, investigate methods, and suggest solutions. In addition, if publicly available knowledge can solve the problem, it might save time in recommending solutions for the particular project. Stating a hypothesis is also not mandatory in Practical-Research. However, suggesting a tentative solution for the problem can help in focusing the investigation, thus making the research more efficient (quicker and less costly).

Developing a Research Method and Plan: Since Practical-Research must be concluded in a very short time and since the budget is usually very limited, an extremely efficient research plan is needed. Such a plan needs to fit the design phase, schedule, objectives, budget, and other constraints (such as the researcher’s own expertise and available tools), in the best way. The research methodology in the schematic design phase will most likely be based on computer simulation to compare the performance of design alternatives. Because of the iterative nature of the design process, it is important to take into (financial) consideration that the simulation may be repeated several times. If there is a requirement to meet specific performance standards, such as LEED’s (Leadership in Energy & Environmental Design) daylight credit 8.1 (USGBC, 2011), then an additional simulation of the final design (after finalizing the construction documents) will be needed. If the budget allows carrying out mock-up experiments and post occupancy evaluations, these could contribute greatly to the design. Finally, further refinement of the research plan, even after the acceptance of the research proposal, may yield better results.

Submitting a Research Proposal: If a consultation service (such as a daylighting expert) is not provided (which is not recommended), it is critical that the proposal for Practical-Research will include verifying the implementation of the research conclusions in the construction documents, during construction, and during the building operation. Otherwise, it is most likely that the research recommendations may not be implemented. Since Practical-Research must usually be completed within a specific design step, the approval date of the proposal must allow sufficient time to carry out the research.

Collecting Data: While in academic research experiments or surveys often take a long time and may include many participants, Practical-Research must be performed in an extremely short period. Practical-Research is most beneficial during the schematic design phase, when design alternatives often change quickly. As a result, the research outcome is usually needed very quickly. In the schematic design phase the Practical-Research will most likely not include occupants (since the building is not built yet); but rather will be based on carrying out computer simulation (which enables quick evaluation of expected performance).

Analyzing Data: In contrast to academic research, which often includes comprehensive analysis of a large database, Practical-Research usually carries out a focused analysis of limited architectural alternatives. The analysis should be able to identify which alternatives perform better, and to what extent (preferably in measurable metrics), as well as test compliance with relevant performance standards (such as daylight standards).

Conducting Synthesis: Although synthesis is not mandatory, it can assist in solving related problems (which may arise during the design process), and can help with the implementation of the research findings in the project. Synthesis is beneficial due to the limited time and budget available for Practical-Research; and since the research findings in Practical-Research are meaningful only if they are implemented in the project.

Drawing Conclusions: In contrast to academic research, where conclusions are mainly used to enrich the public knowledge (by advancing the state-of-the-art), to deliver guidelines, and to share generic solutions, in Practical-Research the purpose of the conclusions is only to provide specific recommendations for improving a particular project. Therefore, conclusions in Practical-Research should be oriented only for project improvement. Since budget and other constraints have a dominant effect on the selection of a design alternative, it is best not only to recommend an 'ideal' alternative, but also to provide a comparison with the performance of other design alternatives.

Submitting a Report: The project-specific recommendations should be presented as clearly as possible to enable the design team and clients to understand them. It is best to submit the report first to the architect (and project manager) in order to test their responses, before delivering it to other members of the design team and to the client. If needed, this may help to reorganize the report more clearly, to focus on the preferred solutions, and to prevent confusion. Presenting the report to the design team and client along with its submission can provide a better understanding; as a result it may encourage a positive response and induce correct implementation. The report may also include recommendations for further research; however (unlike academic research) in practice if such a research is not practical (due to schedule and budget constraints) it is worthless. Furthermore, if additional research is not essential for the success of the project, the client may not appreciate funding further research.

Conceptual model for integrating Practical-Research in the architectural design process

Numerous architectural design fields requiring expert knowledge (such as daylighting, natural ventilation, thermal, solar shading, acoustics, etc.), can benefit from carrying out Practical-Research. Figure 2 presents an illustration of a conceptual model of the design process, expert knowledge, and Practical-Research. The illustration presents a plan projection of a three-dimensional model. The architectural design process is located in the middle and selected design fields requiring expert knowledge are located around it, then finally supporting Practical-Researches are further connected to selected expert fields. If the expert knowledge, acquired by past experience or literature, is not sufficient to provide optimal solution for the design problem, then Practical-Research may be beneficial. Practical-Research may be required to support different expert fields according to the nature of the project. Dots represent various actions: a single green dot, drawing recommendation based on personal expert knowledge (acquired by past experience, literature, etc.); two green dots, establishing an inquiry for Practical-Research and delivering recommendations according to the Practical-Research results; and blue dots, typical Practical-Research steps.

The architectural design is a process that consists of several phases, most of which require the integration of expert knowledge, and some of which could also benefit from utilizing information generated thorough Practical-Research. Figure 3 presents a different projection of the model (a conceptual model of the design process, expert knowledge, and Practical-Research). It is a cross section of the three-dimensional model, showing the relationship among these, in a selected expert field (such as daylighting) and during different design phases, where the vertical axis represents time. Lines represent a general information flow during the architectural design phases (and often an iterative information flow especially during the schematic design phase). In general, architectural design utilizes practical knowledge, experts provide technological knowledge, and Practical-Research generates semi-scientific knowledge. The term semi-scientific is used since on the one hand, the knowledge is generated by scientific methods and tools; however on the other hand, the outcome usually supports a specific project and is not published. Practical-Research may support all design phases. However, it is likely to be implemented in two key design phases: Schematic Design & Construction Documents.

Since each of the tasks requires different skills and processes, it is best if these are carried out by different professionals: an architect, a consultant, and a researcher. Although in practice consultation and Practical-Research might be carried out by the same expert or even by the architect, dividing each design field (such as daylighting) into these three major processes helps to distinguish between them. As a result, even if these tasks are carried out by a single professional, the various processes become more coherent.

The three different processes have different nature. The architectural design process (either a traditional process or a more advanced Integrated Design Process – IDP) utilizing comprehensive thinking; consultation processes, continually providing expert knowledge to the architect and ensuring implementation of the expert features of the design (such as daylighting systems); and Practical-Research, which consists of a short and focused investigation process carried out at a specific design step, when needed. The design process may accommodate several Practical-Research studies, each of a short duration. They are autonomous processes, which require completion of the proposed sequence, typically within a relatively short time, and within a single design phase.

On the one hand, Practical-Research is simply required to generate missing (but potentially valuable) information to the design team. Therefore, it is usually a very short process, which may be carried out during certain stages of the design. On the other hand, consultation is often a long process, accompanying all stages of the design, and the numerous iterations of the design process. In addition, consultation is responsible for integrating Practical-Research when needed; and then ensuring the implementation of the research conclusions in the design, construction, commission, and even in the operation of the completed building.

Although it is tempting to describe on-going tasks as Practical-Research too, such as continually providing expert knowledge to the architect and ensuring implementation of daylighting design recommendations, this model strictly defines such tasks as belonging to a different process, referred to as consultation. This allows the Practical-Research process to remain focused (as required), while still allowing it to remain practical (and thus, to be successfully implemented). Similarly, although it is tempting to assign to the architectural design process the consultation tasks, this model differentiates between the processes. By defining clear boundaries between the three processes, the model becomes more coherent. The consultation process facilitates a better design by providing an immediate response to the iterative architectural design process and by channelling information from (and to) Practical-Research. The information flow during the various architectural design phases may be iterative, especially during the schematic design phase. Since the characteristics of design and Practical-Research are quite different, consultation, connecting the two, needs a constantly shifting mode of thinking between the following set of characteristics (the first of design and the second of Practical-Research): between making (defining best application) and finding (inquiring to reveal truth); between a synthesis process (holistic approach) and an analysis process (focused approach); between solution oriented and problem oriented; between an oscillation process (between solution and problem) and a linear process (from problem to solution); between understanding forms and understanding abstract information; between working with sketches (searching for solutions and problems at the same time) and working with numbers and graphs.

The daylighting workflow

To illustrate the conceptual model for integrating Practical-Research in the architectural design process a daylighting workflow was developed (see Figure 4 in the electronic appendix for an outline of the daylighting workflow). The daylighting workflow comprises several process diagrams; following the diagrams, specific steps are described in more details. The workflow is designed to support research in architectural practice for achieving better visual comfort and energy conservation in offices worldwide and in particular in sunny regions. The daylighting workflow seeks to ensure that all possible design issues that affect the successful integration of the outcome of research tools (such as simulations) in the design are met. Therefore, the underlying concept of the proposed workflow is that it is comprehensive: all relevant issues are essential parts of the workflow (and not just focused investigation processes using research tools (such as simulations).

The proposed daylighting workflow, consisting of the following six major sections, organized in hierarchical order (from comprehensive view of the process to elaboration of key steps): general daylighting information flow during the architectural design process; a typical iterative information flow during a schematic design step; a typical daylighting Practical-Research process; sub-process of the typical practical research process, defining problems & stating objectives and developing research methods and plan; and further elaboration of the primary Practical-Research method of evaluating design alternatives (either by comparing design alternatives set in advance or by a trial and error evaluation process) and other Practical-Research methodologies (such as revealing potentials and problems, optimizing performance, generating innovative solutions, and validating compliance with performance targets and standards).

Daylighting Practical-Research during various phases of the design process

In daylighting design, Practical-Research is especially important in two design steps: *Developing Fenestration Configurations* (which have the greatest effect on daylight) and *Ensuring Quality* (often required for standard compliance, such as LEED). In fact, if the budget is very limited, integrating Practical-Research only in these steps may provide the most valuable information. If budget and schedule allow, Practical-Research may provide significant contribution in other design steps. An overview of the types of Practical-Research which may be carried out during the various design steps is outlined below:

In the Pre-design Phase, Practical-Research carried out as part of an *Initial Design Workshop (Charrette),* which may involve preliminary simulations of daylighting alternatives, can reveal daylight potential or daylight problems, informing preliminary design decisions. A conventional baseline model (including conventional daylighting design) can be prepared in advance to be used as reference for discussion and for a quick investigation of alternatives. During the Schematic Design Phase, in the step of *Identifying the Occupants Specific Needs*, Practical-Research, based on occupants' survey (of employees of a firm moving to new offices) can help specifying the occupants' exact needs. In the step of *Developing the Building Layout*, Practical-Research, based on simulation of daylight alternatives, can help to select the best facade orientation, window locations, and general location of working areas (for maximizing daylight while minimizing summer solar loads and glare). In the step of *Developing Fenestration Configurations*, Practical-Research, based on simulation of daylight alternatives, can help in optimizing fenestration configurations to achieve maximum performance (for example, maximizing daylight while minimizing summer solar loads and glare). In the step of *Developing Interior Settings*, Practical-Research, based on glare simulation, can help in identifying the best interior setting to reduce glare at occupants' visual fields. Lastly, in the step of *Developing Lighting Setting*, Practical-Research, based on simulating daylight controls, can help in identifying optimal zoning of artificial lights, light control strategies, and location and settings of sensors.

The schematic design phase is highly iterative, but Practical-Research often has a tight schedule and limited budget, so the timing of initiating Practical-Research is critical. It should be carried out once the selected alternatives are somewhat consolidated, but before the design is finalized (when no additional time and resources are available for further improvements). Therefore, it is recommended that the daylighting consultation process should consist of first generating and evaluating various daylighting alternatives through the traditional systematic inquiry carried out by sketching; then narrowing them to a limited number of practical design alternatives to be further evaluated through a focused Practical-Research.

In the Design Development Phase, Practical-Research, based on daylight simulation, can help in finalizing the architectural details. During the Bidding Phase, in the step of *Conducting Value Engineering*, if value engineering is applied, Practical-Research, based on daylight simulation, may be needed in order to verify minimum negative impact on daylight performance and to evaluate the final performance, to ensure meeting daylight standards. During Construction Documents Phase, in the step of Ensuring Quality, Practical-Research, based on daylight simulation, is often required in order to evaluate final performance, ensuring compliance with daylight standards, such as LEED, credit 8.1 (USGBC, 2011). The submission of the simulation results to the standard office may be required as well. During the Construction Phase, in the step of *Evaluating Examples*, in case of a large scale project, Practical-Research, based on daylight mock-up may be practical for evaluating final performance, ensuring meeting daylight standards and examining technologies.

In the Building Operation Phase, *Post Occupancy Evaluation* may utilize Practical-Research for fine tuning of daylighting systems and their operation, as well as to obtain valuable practical information for future projects. Practical-Research at this step typically involves a survey that may include monitoring daylight performance and system operation, interviews, and questionnaires. The outcome may include recommendations for a new operation and clearer instructions. Sharing the conclusions with other professionals and the public may support the global effort for improving sustainability in buildings, but this is rarely done in practice.

Conclusions

The research led to the development of methodological recommendations for integrating research in architectural practice. Such research is a modified version of academic or applied research methodologies, designed to accommodate the nature of the architectural practice as well. However, since its scope and objectives are substantially different from those of an academic or applied research, the term *Practical-Research* was proposed for such an investigation. The design process may accommodate several Practical-Research studies, each of a short duration. They are autonomous processes, which require completion of the proposed sequence, typically within a relatively short time, and within a single design phase. The steps and their order of a *typical Practical-Research process* are fairly similar to a process of applied or academic research, however to fit the architectural practice they include modifications (with practical nature). In order to take full advantage of such a research a conceptual model for integrating Practical-Research in the architectural design process was suggested. The model proposes a better integration of Practical-Research in the design process, by utilizing a comprehensive approach to organize the relevant tasks required for an effective design of expert fields (such as daylighting), according to the major design phases and according to the required expertise: architectural design, expert consultation, and Practical-Research. Although in practice consultation and Practical-Research might be carried out by the same expert or even by the architect, dividing these three major processes helps to clarify the various tasks. To illustrate the model and provide a practical tool, the conceptual model was further developed into a daylighting workflow. The workflow provides a roadmap of carrying out several methods of Practical-Research, using scientific tools (mainly daylight simulations), supporting the daylighting design process. The daylighting workflow may be used to develop an expert system program, helping designers and experts through the processes of daylighting design and research in architectural practice. In addition, the proposed workflow may be applied, with appropriate modifications, to other expert design fields, such as solar shading, thermal properties, acoustics, and natural ventilation.

Figures

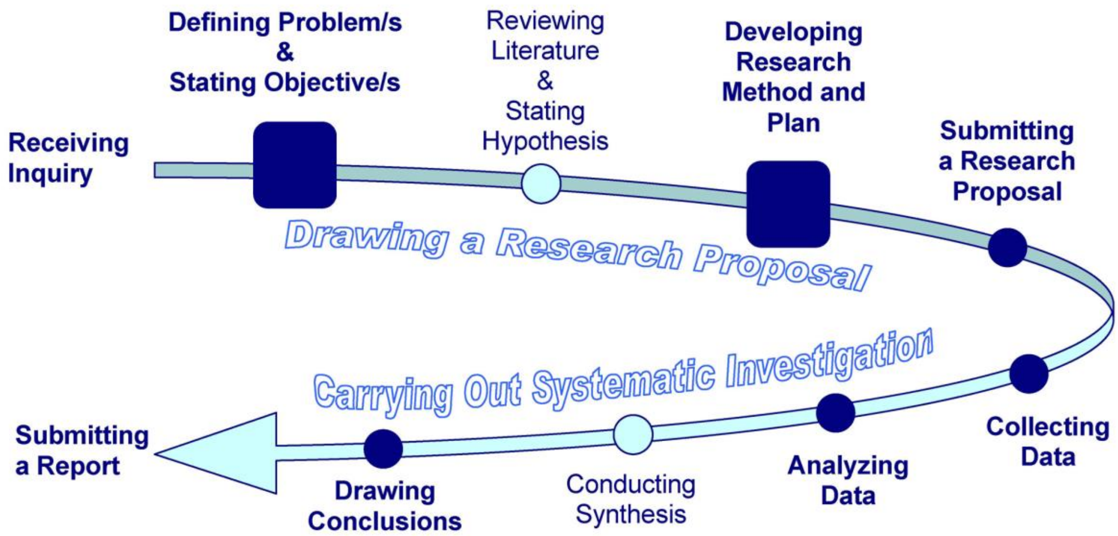

Figure 1 a typical practical-research process

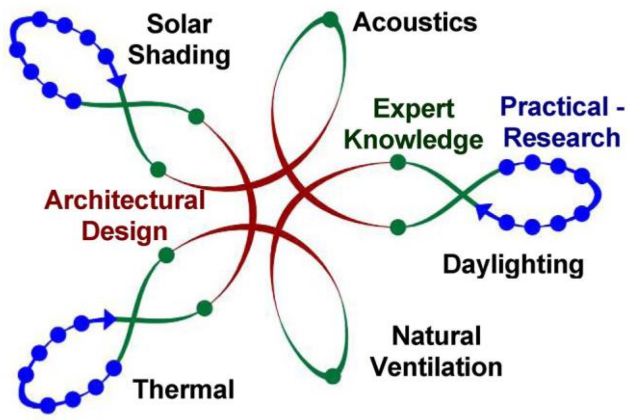

Figure 2 a plan projection of a conceptual model of architectural design, expert knowledge, and practical-research

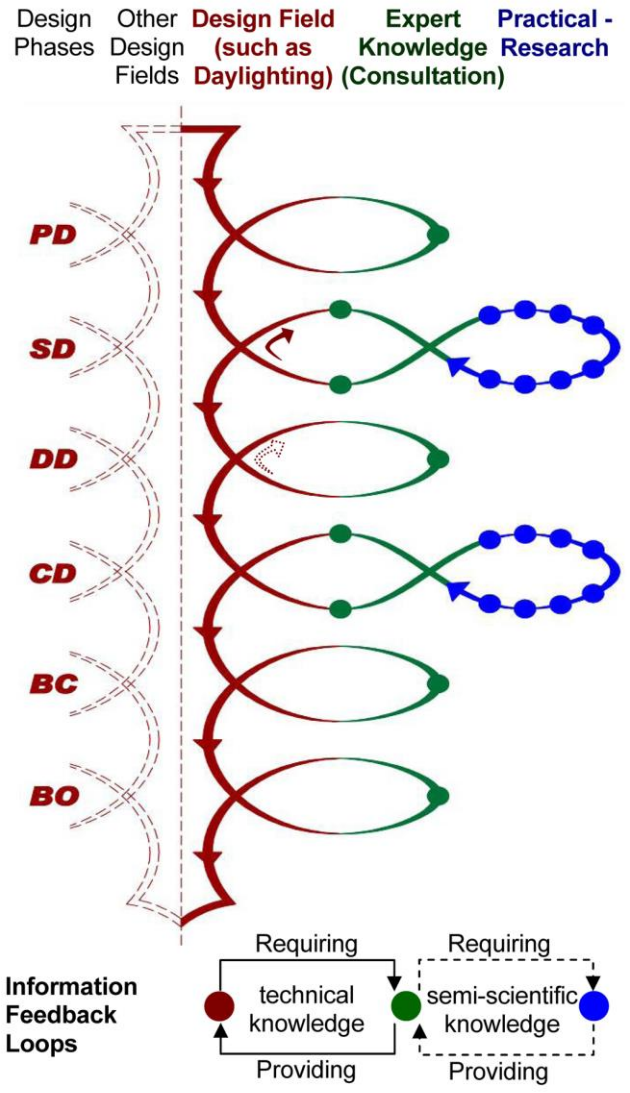

Figure 3 a cross section of a conceptual model of daylighting design process, selected expert knowledge, and practical-research

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