Research Collaboration with the Architectural Design Process: Co-Development of Problems and Solutions

บูรณาการการค้นคว้าวิจัยกับกระบวนการออกแบบสถาปัตยกรรม: การพัฒนาร่วมกันระหว่างโจทย์และผลลัพธ์

Narongpon Laiprakobsup
ณรงพน ไล่ประกอบทรัพย์

Faculty of Architecture, Kasetsart University, Bangkok 10900, Thailand
คณะสถาปัตยกรรมศาสตร์ มหาวิทยาลัยเกษตรศาสตร์ กรุงเทพมหานคร 10900
E-mail: narongpon.l@ku.ac.th

Abstract

This research aims to investigate what a possible framework design research can be integrated with the architectural-design process. The process of design embodies dialectics between generation of form and research. How strategic design research is cooperative into design processes to achieve the design solution has been barely examined in a broad range of the architectural-design practices. The study thus explores a comparative analysis of the design processes in different design practice between third-year architecture students, fifth-year architecture students, and architects, to examine various forms of design research taking place in finding and solving problems.

Findings reveal that design research lies in investigative modes and processing of external knowledge relevant to problems, thereby enabling for a decisive solution. Research cooperates with the design process as learning tensions between problems and solutions. However, the problem-solution pairing and research taking place do not promise the successful solution. The acceptable design unfolds continuous improvement between a series of problems-solutions through which research induces the co-development of problems-solutions framework from an abstract idea to concrete levels of design development in three situations: "understanding criteria and formulating goals," "exploring possibility," and "examining reality." Moreover, practitioners mostly draw upon more design visions to direct problem-framing, research, and working methods to meet design goals than novice students operate research into the process of design.

To effectively implement research into the design process, a designer could consider design activity as a critical learning process as the co-development of problems-solutions framework to operate design strategies and thinking. This mode of design thinking will allow design research roles to collaborate with problem-framing and design methods into the design process.

บทคัดย่อ

การวิจัยนี้มุ่งเน้นการค้นหาความเป็นไปได้ของการทำงานร่วมกันระหว่างการค้นคว้าทางการออกแบบกับกระบวนการ ออกแบบสถาปัตยกรรม ที่เกี่ยวข้องกับการสร้างแบบแผน/รูปทรงทางสถาปัตยกรรมและการค้นคว้าวิจัย อย่างไรก็ดี วิถีทาง ของการประยุกต์การค้นคว้าวิจัยร่วมกับกระบวนการออกแบบเพื่อบรรลุถึงผลลัพธ์ แทบจะมิได้รับการค้นหาความสัมพันธ์ ในเชิงกลยุทธ์ที่จริงจัง ในวงกว้างของการฝึกฝนการออกแบบสถาปัตยกรรม ดังนั้น การวิจัยนี้เป็นการวิเคราะห์เชิงเปรียบ– เทียบของกระบวนการออกแบบในความแตกต่างของการฝึกฝนทางการออกแบบ ระหว่างนักศึกษาสถาปัตยกรรม ชั้นปีที่ สาม ชั้นปีที่ห้า และสถาปนิก เพื่อตรวจสอบรูปแบบที่หลากหลายของการค้นคว้าวิจัยในการค้นหาและแก้ไขโจทย์ปัญหา

ผลการวิจัยชี้ให้เห็นว่า การค้นคว้าทางการออกแบบเป็นวิถีของการสืบสวน และประมวลองค์ความรู้ใหม่ที่สัมพันธ์ กับโจทย์ปัญหา ซึ่งสามารถนำไปสู่การเสนอผลลัพธ์ทางการออกแบบที่ชัดเจนและตอบสนองกับโจทย์ การค้นคว้าสามารถ สอดประสานร่วมกับกระบวนการออกแบบในแนวทางความสัมพันธ์ของการเรียนรู้ระหว่างโจทย์ปัญหากับการเสนอผลลัพธ์ อย่างไรก็ดี คู่ความสัมพันธ์ระหว่างโจทย์ปัญหากับผลลัพธ์ และการดำเนินการค้นคว้าวิจัยมิได้ยืนยันถึงผลลัพธ์ทางการ ออกแบบที่ประสบผลสำเร็จ ขณะที่ผลงานการออกแบบซึ่งเป็นที่ยอมรับแสดงออกถึงการพัฒนาที่ต่อเนื่องระหว่างคู่ความ สัมพันธ์ระหว่างโจทย์การออกแบบและผลลัพธ์ โดยที่การค้นคว้าวิจัยส่งเสริมโครงสร้างการพัฒนาร่วมกันระหว่างโจทย์ปัญหา และผลลัพธ์จากแนวคิดเชิงนามธรรมไปสู่รูปธรรมทางกายภาพของการพัฒนาการออกแบบในสามสถานการณ์ อันได้แก่ "การสร้างความเข้าใจเกณฑ์และการตั้งเป้าหมาย" "การค้นหาความเป็นไปได้" และ "การตรวจสอบความเป็นจริง" นอกจาก นี้ ผลการวิจัยแสดงถึงว่า สถาปนิกมักประยุกต์วิสัยทัศน์ทางการออกแบบในการเรียบเรียงโจทย์ การค้นคว้า รวมถึงวิธีการ ค้นหาเพื่อบรรลุถึงเป้าหมายของการออกแบบ มากกว่านิสิตในการดำเนินการค้นคว้าภายในกระบวนการออกแบบ

ดังนั้น นักออกแบบควรพิจารณาการออกแบบสถาปัตยกรรมซึ่งเปรียบได้กับกระบวนการเรียนรู้เชิงวิพากษ์ในแนวทาง ของการพัฒนาร่วมกันระหว่างโจทย์ปัญหาและผลลัพธ์ เพื่อดำเนินการและกำหนดกลยุทธ์ทางการออกแบบ แนวทางการ ออกแบบดังกล่าวจะทำให้บทบาทของการค้นคว้าวิจัยทางการออกแบบสามารถทำงานร่วมกับการเรียบเรียงโจทย์ปัญหาและ กลวิธีการทำงานในกระบวนการออกแบบอย่างมีประสิทธิภาพ

Keywords (คำสำคัญ)

Design-research Collaboration (การทำงานร่วมกันทางการออกแบบและการค้นคว้า)

Co-development of Problems and Solutions (การพัฒนาร่วมกันของโจทย์และผลลัพธ์)

Architectural-design Process (กระบวนการออกแบบทางสถาปัตยกรรม)

Design Research (การค้นคว้าวิจัยทางการออกแบบ)

Design Inquiry (การสืบสวนทางการออกแบบ)

1. Introduction: Architectural Design as a Generative Inquiry

Design research becomes more significant for inducing critical thinking and ideas in architectural design. Dialectical relationships between design and research, as two different modes of thinking, however cooperate in design processes in complex ways. What possible design research is associated with the architectural-design process lies in the core of this study. The process of architectural design is considered as a series of design actions while design research functions as investigative modes to resolve design problems toward the creative design solution. In this view, design research is important for the process of design in that architectural design obtains a constructive form of the future solution through design research as investigations of critically learning possibilities, which develops a systematic design approach, that is, not solely dependent on cognitive intelligence.

This research is based upon the assumption that architectural design as a generative inquiry is an evolving process, which contains constructive and investigative frameworks coming into comprehensively and systematically reasoning a design proposal. If designing performs itself as a constructive inquiry of form, "design as research" emerges out of the aims to generate figural reality in parallel with employing propositional methods or schematic activities of analysis (Groat & Wang, 2002), which are involved in the design process to culminate into a project-specific solution. Design as research, as to Jan Stappers (2007) and Horayangkura (2002), embodies design problems of motivation as well as creative and evaluative processes that lead to a resolved, creative product. In this light, inquiries of architectural design continue with tensions between framing design problems and finding appropriate solutions that enable investigative procedures, namely design research, to integrate within the design process. Based upon design as an inquiry, design

research as investigative modes can plays collaborative roles in any stages of the design process and creativity (Horayangkura, 2004).

Methodological conflicts between design and research, however, seem to manifest a difficulty of the creative collaboration with the process of design. Designing performs in the synthesizing way of thoughts or a solution-focused strategy; on the other hand, research mainly depends on logical procedures. The nature of research collaboration with the architectural design process has barely been addressed in architectural theory and design education, especially in design methodology of how design research exists in the process of architectural design. As a scientific paradigm of analysis/synthesis/evaluation has fallen down to embrace the intrinsic nature of design thinking and pragmatic realms, this study aims to set a collaborative "design-research" paradigm on a constructivism stance, based upon following objectives:

1. What a possible framework design research exists in the architectural-design process.
2. What research roles act upon design processes for generating environmental forms.

Understanding of the research collaboration with the design process and its functionalities will contribute designers, especially for novice students in environmental design fields, to new insights into advancing the cooperative design-research strategies throughout the process. As a constructive development of environmental forms, the design-research paradigm will enhance critical thinking of design in integrated, progressive methods.

2. Reflections on the Structure of Design Inquiry

The intrinsic nature of the architectural-design inquiry seeks the integrated solution of the built environment responding to determinate design tasks. Design inquiry is pertinent to the design process—a series of design actions of complex problem-solving, a solution-oriented creativity. The process of design lies in fundamental acts of problem-structuring and

developments of design solutions toward the design product. In this way, design inquiry manifests itself a dialectical process of problem-framing and solution-finding as "co-evolution of problem and solution" (Dorst & Cross, 2001). With critical investigations, the design process needs to cooperate with design research as constructive methods that offer systematic approaches to architectural design.

2.1 Design Problem-Solving

Architectural design inquiry aims to figure out design tasks and to create what an environment might be and how it functions in the possible future. Design problem-solving dealing with solution-making is distinctively recognized from scientific counterparts in general. Scientists use a problem-focused strategy to solve problems by analysis; conversely, architects adopt synthesis as a solution-focused strategy so as to figure out an acceptable outcome responsive to the problems. Designers progressively comprehend the intrinsic nature of the design problems as they work out on solutions whereas scientists rather pay attentions on discovering elemental codes of the problems as much as possible before making solutions (Lawson, 2006; Cross, 2007).

As Cross (2011) proposes, design thinking and rationality chiefly employs a different mode of logical forms to problem-solving, namely abductive logic for productive reasoning of what a form may be suitable for given problems and conditions. Abductive logic suggests the way to build a design hypothesis (Augustin & Coleman, 2012); it indicates the act of generating design conjectures as initial visualization of any configuration response to problems. Design rationality of envisioning the relationships between problems and conjectures attaches design problem-solving to creativity.

Creativity in recent research demonstrates as the synthetic process of thinking and making— generative drives from conception toward reality in a perspective of inclusivity, opposed to a moment of creative leap (Anthoniades, 1992; Lawson, 2006). As

Lawson (2006) indicates, creative accomplishment seems to progress into the following critical steps: initial awareness and inquiry of problems, blueprint visualization of the solution as a key concept, and developing phases of elaboration and verification. The tensions between problems and solutions are vital to creativity, including design developments. All of these recognized creative sequences go on continuously throughout the design process.

The relationships between design problems and solutions are critically complex. There are no objective formulations to define design problems as ill-defined and wicked as significantly obliged to designing, and to create solutions (Rowe, 1991). However, clarity of design problems begins to emerge when some ideas to create solutions are demonstrated. During the process, reframing problems and developing solutions are mutually advanced in parallel lines of design thinking (Rowe, 1991; Lawson, 2006; Dorst & Cross, 2001). "Co-evolution of problem-solution," as to Maher, Poon & Boulanger (1996) and Dorst and Cross (2001) propose, refers that problem and solution spaces transact information between the two domains of design inquiry so as to improve problem clarification and solution ideas by matching problem-solution pairing. This investigative process as structuring organization of design inquiry enables design research to take place as framing and reframing drives as strategic methods. However, research operations in the co-development of problems-solutions mode are not recognizably concentrated on an inclusive examination. What possible design research could lend itself to be incorporated into the design process of multi-dimensional synthesis of forms is raised.

2.2 Design Process

The design process is to establish design methodology as a discipline: it is involved with formulation of controlling data, design strategies, and design decision. The process of design intends to help designers make clear of problem-structuring and modes of solution-making (Lawson, 2004). Design

methodologists, since early sixties, have initiated three main models of the design process: 1) analysis/synthesis/evaluation; 2) conjecture/analysis; and 3) primary generator/conjecture/analysis.

The *analysis/synthesis/evaluation* model was formulated through positivist, scientific methods, based on inductive reasoning of information processing to create a form responsive to design tasks, instead of traditional design from experience and preoccupied interests. Analysis is viewed to be the initial step to gather valid facts for problems and sub-problems and to realize design situations and criteria. Analysis would lead to synthesis of finding out sub-solutions as evaluation takes place to test, select, and integrate sub-solutions into the overall solution (Downing, 1989; Rowe, 1991). This model is identified as system theory in design practice. However, this model has been fallen down due to its opposition to the nature of architectural-design thinking that incorporates analytical facts with environmental symbol-making. Moreover, designers need to spend a plenty of time to research and verify empirical facts without a focus of the deductive concept to guide design research.

Design theorists better understood designers' intuition in the creative process and developed a new design process, the *conjecture/analysis* model. This model aims to cooperate with a combination between subjective intellectual efforts and objective accounts for programming and solution assessment. Conjecture, as Hillier suggests, indicates building up intellectual capacity of the problem and solution relationships while analysis refers to operating and applying spatial, formal, and ordering principles discovered in the conjectured solutions to agree with design assignments (Downing, 1989). Problem-structuring is on initially intentional emphasis by highlighting hidden, relevant knowledge such as precedent studies and construction methods. Programming turns into designers' responsibility through research to form criteria and architectural problems (Pena & Parshall, 2001). The *conjecture/analysis* model employs the process of "variety

reduction" to minimize possible solutions by assessing an alternative solution against project constraints, social and cultural factors, and designers' cognitive structuring (Downing, 1989). This model enables design research to incorporate with both program-building and design assessment throughout the whole process of design.

Rather than using conjectures in articulating design strategies, architects convey a "hidden agenda," namely termed primary generator. The *primary generator/conjecture/analysis* model reveals a set of vital characteristics of the problem—reflected in an original conjecture of what an anticipated place might be, and then develops design conjectures and other problem aspects (Darke, 1979). The primary generator might be derived from high values on subjects of programs, site constraints and specific contexts, and individual interests, often including worldviews—especially for experienced designers to drive the design generator (Lawson, 2006). When focused principles are posited against local external constraints, design issues are likely to emerge collectively and lead to the principal solution toward the central concept or *parti* as a major ideal diagram dominating design schemes and development (Astoniades, 1992; Lawson, 2006). The primary *generator/conjecture/analysis* model enables for organizing design strategies and research regarding main conjectures. Its process offers research episodes inclusive of design understanding, challenges, and developments in an integrative fashion of design nature.

2.3 Design Research as Investigative Modes

Architectural design and research can coexist in the process, but create logical difficulties due to a contradiction between non-proportional, design thinking and a scientific framework of what to be examined (Groat & Wang, 2002; Ganshirt, 2007). If the design process is recognized as a generative inquiry, design research performs as *investigative modes* in relation to imposed design questions and key problems

addressed in design situations. Design research implements differently interdisciplinary perspectives and design visions into actions to attain to new ideas (Schneider, 2007). Design research affording critical methods helps a designer systematize a design framework to (re)define problems and (re)evaluate design alternatives, including decision-making that shapes the creative development (Augustin & Coleman, 2012).

Design research can take on several forms of investigations and experiments: qualitative and quantitative approaches in environment-behavior design. According to Zeisel (2006), and Augustin and Coleman (2012), both qualitative and quantitative methods offer a diversity of tactics: literature review, case studies, observations, interviews, behavioral mapping, and questionnaires, all of which are contingent on design situations. In addition, "design tools" such as sketching, drawing, diagramming, modeling as immediate mediums of generative visual and spatial articulations can be considered as exploratory part of generative modes of designing, with comprehending and examining interdependent factors of design (Ganshirt, 2007).

Groat and Wang (2002) propose possible models to conduct "episodic research" into the process of design: programming and post-occupancy evaluation, design as action research, design as learned skill, and design collaboration. These design approaches make an attempt to draw analytical research into the larger domain of design. However, these frameworks only manifest gateways of research cooperation with design activity, rather than clarify how designers pragmatically organize the interrelated complex inquiry of design collaboration with research.

3. Research Methodology

The processes of architectural designing and thinking are naturally complex in the way that designers operate design activity in the process dealing with problem finding and solving. Thus, this research aims to understand and reconstruct reality of design nature cooperating with research. Its framework stands on a naturalistic inquiry on participant observations for collecting and decoding data in design-research operations.

3.1 Hypothesis

The research hypothesis is established to investigate what a possible framework for the architectural-design process presents for research, and what roles of design research drive problem-solving in design thinking and inquiry. Architectural design is the collectively synthetic operation so as to generate the specific, physical solution. If the architectural-design process is an inquiry leading to the creative formal solution, then it requires collaborative research strategies and tactics for investigating an appropriate, figural solution responsive for key problems. The architectural-design process can therefore integrate with design research in terms of *dialectical design dialogues between problems and solutions*.

3.2 Subjects of Study

The research included three different groups of design participants: third-year architecture students, fifth-year architecture students, and professional architects, due to variables of experience and design visions. Samples of design students' tasks followed the curriculum of Faculty of Architecture, Kasetsart University as professional participants integrated their practices with research. The first group of eight third-year students was initially trained for integration between design and research. The second group of six fifth-year students conducted design theses, including programming. And, the third group consisted of five practitioners who collected more experience in design inquiry than the other previous groups.

3.3 Procedures

Data collection and analysis are based upon a theoretical proposition that design and research can be incorporated if the design process is considered

as an inquiry enhancing the problem-solution relation-ships. This proposition helps to focus on data reduction and determine relevant data. Data gathering depends upon participant observations, in-depth interviews, and figural records on design processes among three groups of participants from the beginning of varied, design tasks. Data collected from the two groups of students focused on observations on how design students operated design activity and research after getting design tasks and initiating individual, design thesis projects. Data gathering from practitioners relied upon in-depth interviews on design inquiry carried out on specific projects.

As an architectural research on the design process, participant observations regarding a sequence of design activities were first to determine relevance to continuity of the process of design inquiry, especially for design student subjects. Second, design problems, solution developments, and investigative practices taking place were documented in problems-research-solution diagrams, including visual records to describe the progress in design inquiry. Third, interviews of the interactions between design problem, research, solution were collected to investigate what possible design research collaborates with the process.

Data analysis of "unitizing and categorizing" processes was conducted, according to Lincoln and Guba (1985). During the unitizing process, units of meaning retrieved from analytical diagrams of processes, figural records, and interviewed transcripts were compiled in index cards. Meanwhile, the categorizing process was to assemble units relating to the same content of design-research dialogues into category sets and to overlap relationships between categories. Sorting and categorizing were repeated and replicability of categories was contrasting and comparing via other design-research collaboration within and between the groups of participants.

4. Design Inquiry of the Co-Development of Problems-Solutions

Based upon a research hypothesis, architectural design as creative inquiry does not only rely upon a designer's subjectivity, but also turns out to be cooperatively progressive acts of integrating design visions, learning design situations and constraints, and most importantly investigating the novel, appropriate proposal responsive to design problems. A series of dialectical pairs between problem space and solution space give rise to a conceptual framework to which design inquiry and exploration enables to be suitable for the evolving process. In this context, research space can take up an important role in-between the problem and solution pairing in order to figure out design possibilities as well as to understand and reframe problems, specifically integrated with data processing. The following results will unfold how three different groups of designers in diversely collective practices operate processes of designing cooperative with research in the framework of the problem-solution pairing.

4.1 Third-Year Students' Design Process

The design assignment, the site, and requirements were given; its task was to create the *Eco-Adaptable Community* serving for a youth camp and a shelter for flooding evacuation. The goal of the program was to incorporate sustainable orientation into design thinking.

Design research for sustainability issues is essential to establish the design framework and to figure out the environmental-design solution (Hengrasmee & Chansomrak, 2011). Associations between a series of problem-research-solution developments grow to be noteworthy in relation to *programming reorganization* concerning sustainability, which operates in the new patterns and conditions of

spatial functionalities and formal inquiries. The process as shown in Figure 1 revealed that third-year students began to recognize the given task as an initial problem (P_1) that needed to be understood in more clear sense of physical relationships of sustainability to the site. At this point, the first research (R_1) was initiated with the aims of searching for design goals and figuring out the key concept to continue throughout the project. Third-year students usually investigated related case studies, site analysis, and functional relationships in terms of ecological concerns. They employed three different strategies of sustainability to "restructure the program" and organize their design approaches and process to the task:

1. Exploring ecological systems such as water treatment and waste management, and then creating recycling, environmental systems integrating with site constraints (Figure 2).
2. Analyzing specific users' needs and behavior, which affected a distinction of programmatic relationships for spatial flexibilities.
3. Searching for cultural concepts and regional morphology to reflect local connections.

In this stage of research, all students made an attempt to find out their projects' sustainable solutions so that new spatial-sustainable relationships were integrated and reformed into the whole concept as specific, design goals (S_1).
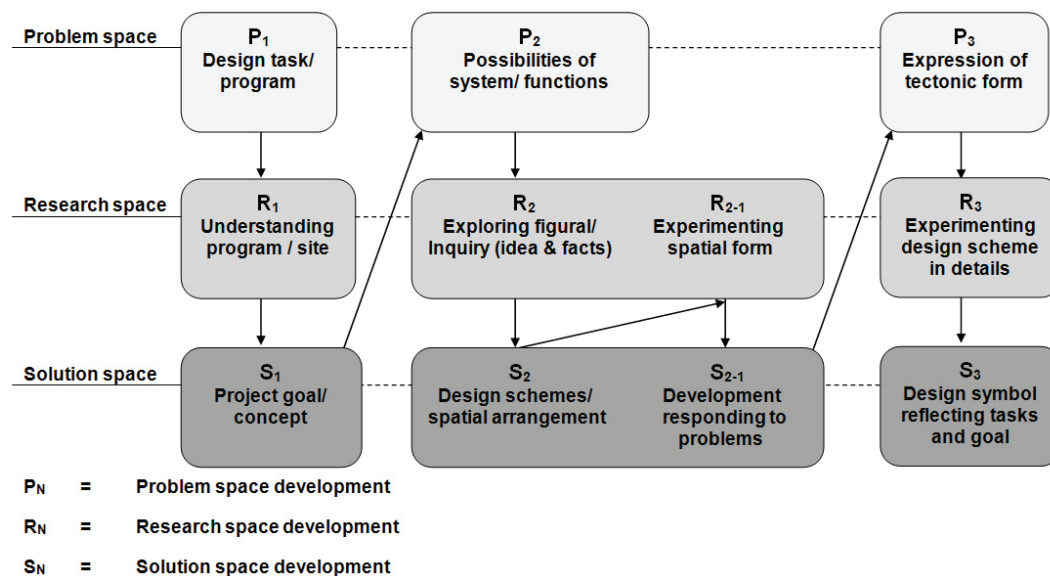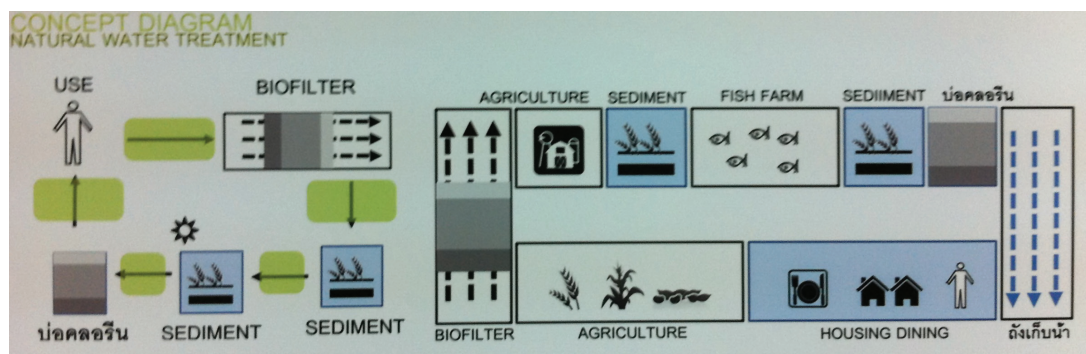

P_N = Problem space development

R_N = Research space development

S_N = Solution space development

Figure 1. The third-year architecture students' design process collaborating with research in the co-development of problems and solutions model.

Figure 2. The generative diagram of the natural water treatment incorporated to required functions and supportive activities concerning an ecological system.

The initial solutions obtained from reorganizing the program would motivate focused research questions or further problems on investigating possibilities of spatial-sustainable organization (P_2). This research phase highlighted physical exploration, that is, formal and spatial experimentation to the site conditions (R_2) cooperative with defined, ecological concepts and created, restructured programming. It can be also observed that designers employed a variety of design tools as methods—sketches, diagrams, drawings, model-making—available for "processing" design ideas and obtained data. This stage of research was taking a greater time than any other inquiry phases because it was great deals of design inquiry to generate a figural conjecture (S_2). Thus, designers had a tendency to divide physical investigation into two sub-phases: 1) schematic inquiry; and 2) spatial form experiment (R_{2-1}) for design development (S_{2-1}).

As third-year students constructed their individual, design schemes in concrete degrees through figural research, these design conjectures had impacts on further developed problems on expression on tectonic form (P_3). In other words, design schemes manipulated what possible design agendas of sustainability designers could better conduct further exploration in details and symbolic proposition of design (R_3) to manifest the vibrant image of the sustainable design concept. Some designers decided to explore structural design and elemental concerns on ecological systems while others focused on investigating socio-cultural spaces. The solution from tectonic research phase aimed to create a design symbol (S_3) reflecting the project's eco-sustainable configuration on the identified design goal and concept.

There is a tendency for third-year students to define specific, ecological and sustainable agendas in order to pilot design problems and research. Sustainable design inquiries within the process are conducted from investigating an appropriately ecological system to the site constraints, regenerating new programming conditions: functionalities and relationships, to experimenting environmental aesthetics: spaces, forms, and elements. In this regard, determinate, ecological-spatial diagrams contribute to a promise on spatial management in particular site conditions as architectural functions and symbols are incorporated with defined, sustainable concerns as the integrated whole.

4.2 Fifth-Year Students' Design Process

The design process of fifth-year architecture students is more distinctive than other groups of participants in that fifth-year students' design theses embody researching their own unique programs as design assignments and designing responsive to the program. Both programming and designing are correlated in terms of architectural creativity, thereby considered as the inclusive design process.

As fifth-year students held thesis proposals containing unsettled ideas at hand, most of them concentrated their projects on issues of building typologies whereas the others focused on the selected sites to find out what possible programs would enhance specific locations. Programming lies in critical research, which has effects on the co-development of design inquiries and creative challenges by the way of reinterpreting building typologies and environmental functionalities against existing contexts and future circumstances. As shown in Figure 3, programmatic searches (P_1) were an initial problem to challenge problems of existing conditions of building types and the site. Fifth-year students began to conduct archival search for relevant contents: case studies, documents, codes, and site constraints; all materials had been analyzed and criticized (R_1). In this stage, designers were inclined to be overwhelmed with a lot of information; thus, they employed methods such as diagrams to organize associated data in order to form programmatic concepts (S_1), for instance collaboration between two different building types in place.

Programmatic concepts, in turn, establish a high-level, design problem of de-composing ordinary building types into a new architectural typology,
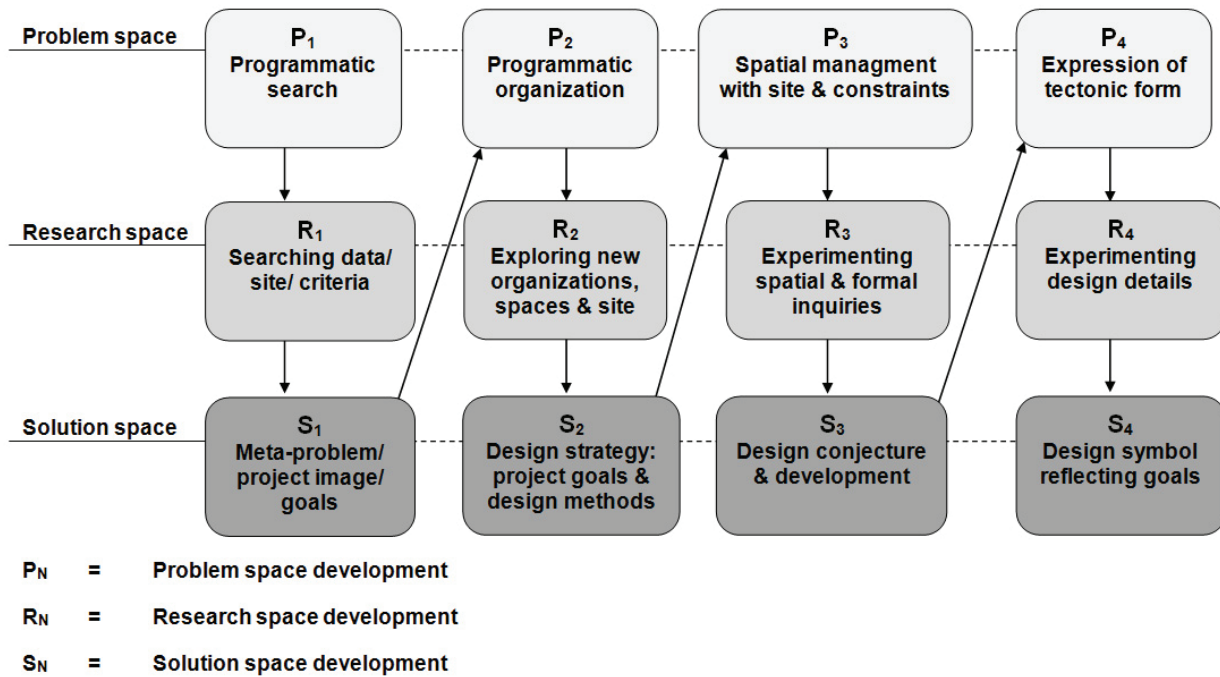
Problem space	**P₁** Programmatic search	**P₂** Programmatic organization	**P₃** Spatial managment with site & constraints	**P₄** Expression of tectonic form
Research space	**R₁** Searching data/ site/ criteria	**R₂** Exploring new organizations, spaces & site	**R₃** Experimenting spatial & formal inquiries	**R₄** Experimenting design details
Solution space	**S₁** Meta-problem/ project image/ goals	**S₂** Design strategy: project goals & design methods	**S₃** Design conjecture & development	**S₄** Design symbol reflecting goals

P_N = Problem space development

R_N = Research space development

S_N = Solution space development

Figure 3. The fifth-year architecture students' design process collaborating with research in the co-development of problems and solutions model.

namely a *meta-problem* (Bamford, 2002). For example, a design task of a new complex to serve catholic life-styles in urban contexts makes challenges beyond designing a monastery, but generates design problems to creatively find out a combination between a monastery and public spaces.

Programming directed meta-problems toward inquiries of programmatic organizations (P_2). Fifth-year students explored novel programmatic systems, the site, and elements (R_2) beyond design requirements so as to construct critical strategies for designing. This research phase of the programmatic collaboration with activity, the site conditions, and constraints would clarify the design goal and problems as well as motivate design strategies (S_2) of how possible architecture would perform in creative modes.

Individual design strategies arranged a quest on spatial management (P_3) with contexts and design criteria. Spatial and formal investigations were encouraged through programmatic challenges. Spatial reorganization of orders, sequences, and volumes was experimented and developed (R_3) along with the site
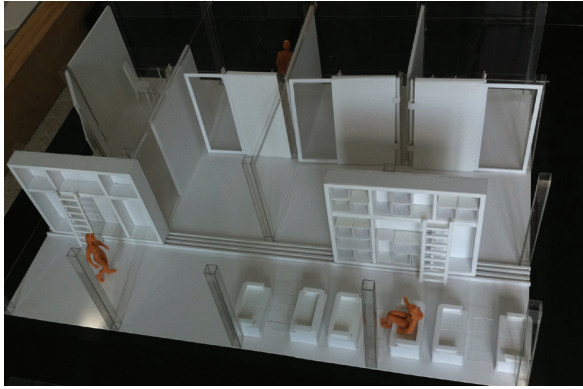
so as to generate design conjectures of physical forms (S_3) in association with distinctive program-matic strategies, namely, "form follows program."

Similar to the third-year students' process, design development in design theses helped to frame focused problems on expression on tectonic form (P_4). Different thesis projects, in the tectonic research, aimed to experiment symbolic details and elements (R_4) with critical concerns to simultaneously construct and check figural configuration on these distinctive approaches:

1. Exploring spatial and formal responses to constraints.

2. Investigating structural configuration related to topographic contexts.

3. Experimenting mechanism of the key spatial units to reinforce project concepts (Figure 4).

Tectonic experiments of all thesis projects intended to manifest designed, environmental symbols (S_4) reflecting particular design goals.

In addition to a continuous development between problems and solutions, it can be observed that if design problems are complex, a designer is

(Source: The fifth-year architecture student from the *Prototype of Clothing Fashion Creation Center Thesis Project*.)

Figure 4. Exploration of modular spatial volumes' flexibility through the movable partition system.

likely to investigate solutions in portions, especially in searches for physical conjectures and development, from forming the whole scheme to refining a tangible, design image. The finding, moreover, shows that to generate a creative design program relies not only on gathering raw data but also on stimulating project concepts or design agendas to control information inputs as well as processing relevant data into a synchronized framework of the emergent programming, that is, actively operating design inquiries and approaches in the coherent progress.

4.3 Professional Architects' Design Process

Professional architects' design tasks were diverse in project scales from interior spaces, domestic domains, to complex projects. However, their design processes were carried on through architectural design thinking of the problem-solution relationships. Architects tended to initiate the process of design with *design visions*, considered as conceptual challenges that guided to frame design problems and strategies.

Design visions help architects to link a dichotomy between research and design in the design process, especially to focus design issues on spatial typology. Spatial typology refers to the pre-existing, environmental reference such as typical spaces, building

types, and urban configuration, from which new design ideas can be evolved. Spatial typology can raise design challenges to which design research and inquiry of existing environmental forms and tectonics can possibly create a novel environmental design.

Design inquiries on spatial typology had effects on the searches for critical design issues: latent patterns that are literal and figurative links related to possibilities of environmental modification. Even if architects did not define design briefs given from clients as design problems, they used design tasks/ assignments as the beginning position as an initial problem (P_1), which needed to be comprehended and figured out toward an original design problem. As shown in Figure 5, architects began the primary research (R_1) with particular design visions or design-team debates of the assignments in an attempt to understand these following issues:

1. Systems of the program: activity relationships, hierarchical orders, and sequences.
2. Case-study analysis to construct design criteria and problems.
3. Constraints: sites, contexts, time, stakeholders.

Professional designers took serious research and discussions on this stage to discover critical design agendas, a project concept/goal, or meta-problems (S_1). In this light, design concepts/goals systematized an organized image of the project, leading to design problems of the environmental reinterpretation.

An original, design problem-framing was more likely to emerge out of the attempt to resolve critical, existing environmental conditions and programs. It was concentrated on exploring design possibilities in physical forms (P_2). In this research stage, most designers emphasized constructing fundamental design conjectures (R_2) through experimentation of reorganizing spatial management against the programmatic conditions and contextual constraints, which depended on concentrated design issues such as spatial systems: adaptation, interpenetration, boundaries, and materiality to reach design alternatives
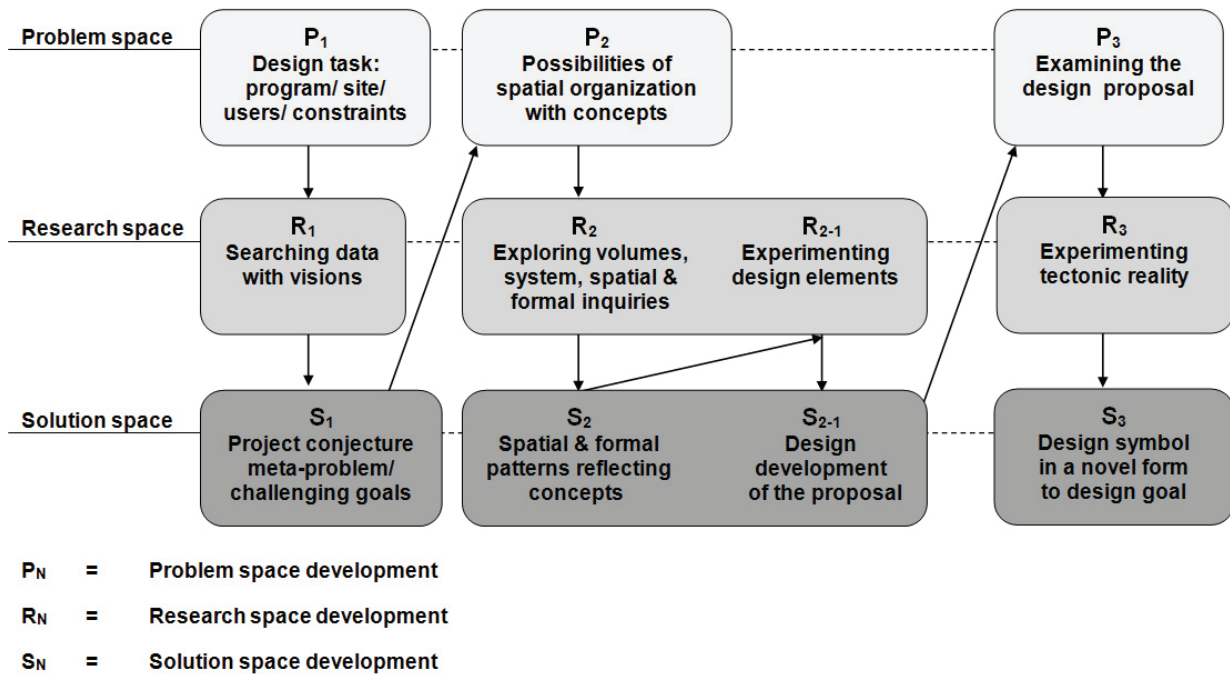
Figure 5. The professional architects' design process collaborating with research in the co-development of problems and solutions model.

(S_2). Designers moved forward to experiment design conjectures and crucial, architectural elements (R_{2-1}) to improve design development. The further figural experiment was to make sure that design proposals (S_{2-1}) manifested design concepts and responded to programmatic and spatial modification in comparison to existing environmental typologies in pragmatic levels.

Professional designers, in addition, developed an advanced problem on examining tectonic form (P_3). Designers mainly focused on experimenting tectonic reality (R_3), after design development, for critical elements, design details, and the construction process to ensure whether prospective design effects expressed and functioned as what designers had speculated. It is noted that architects experiment tectonic research by building mock-ups that get tested in real situations. Rather than acknowledgement of design effects, comprehensive design proposals presenting symbolic creativity of the built environments that are aligned with spatial typology (S_3) can come out of this progress. Design research and inquiries

on spatial typology are capable of regenerating new spatial management as well as creating a unique connection with the existing context in multi-levels: history, tradition, and culture as which modified, challenging environmental forms define it.

4.4 An Observation from the Co-Development of Problems-Solutions

From findings, the architectural-design process acts as a critical inquiry of environmental creativity. The process of design continues on learning lines of thought through finding and solving problems. The process of designerly learning and investigations of design problems and solutions as well as creativity encourages design research to take place in design inquiry. In the light of the dialectic of problem space and solution space, research space lies in transition from tacit states of knowledge and quests to decision-making of the physical form: it performs as a domain of design operations of which to investigate, experiment, and examine. The design framework of matching the problem and solution relationship thus enables

design research to be inclusively incorporated into the design process.

The pairing of problem-solution and research taking place does not ensure an appropriate design solution. However, an accepted design product strategically depends on the progressive development between the problem-research-solution pairing in design phases from design tasks to the environmental symbols. All designers consider design tasks as an initial problem in spite of not being a real design problem. They make an attempt to understand and explore design programs with generic and specific views to set design goals, concepts, conjectures, or meta-problems as an initial solution. A proposed initial solution lends itself to frame the design problem with challenges to induce creativity, correspondingly to Cross's notion that a designer tends to frame design problems with particular views (2011). Moreover, architects mostly draw more design visions to direct problem-framing, research, and strategies to meet design goals than novice students operate research into the process. Architecture students tend to employ agendas related to programmatic contents and sites to begin exploratory research. Due to being less experienced than professional architects, several students have a difficult time to control the process of design and research for both problem-framing and design directions.

Design challenges affect collaborative directions of the design process and research as a roadmap of design inquiry. Designers advance research into exploring architectonic possibilities and examining conjectures in more objective lines of thought with relevant information. The design proposal affects problem refinement in the final phase of design to experiment tectonic form, that is, to present environmental symbols. As design problems and solutions are co-evolved in more concrete levels through which research operates with methods, research space inherently collaborates with the design process in the *co-development of problems-solutions* framework.

5. The Recognition and Collaboration of Research Space with the Design Process

Design and research convey different modes of thinking as to Groat and Wang (2002): design presents itself as formal synthesis while research employs logical analysis. Design research can be yet incorporated into the design process in sequence as well as improve critical design products (Horayangkura, 2002), if designers recognize design activity as a creative inquiry of a series of framing and solving design problems by means of "design through research." Design thinking in *the co-development of problems-solutions* framework offers spaces of design research for creative platforms of data processing in integration with design understanding and exploration.

As Dorst and Cross (2001) propose that the design process for creativity continued in "co-evolution of problem-solution," in which "design space" is enhanced in matching problem and solution spaces, investigative operations to transform an initial knowledge state to a decision domain of potentially proposed design implementation are required. Research space as embedded into a series of problem-solution pairing thus performs as an interval domain of design investigation, and turns into significant design modes to transform design problems to solutions, rather than data collections. It determines design decisions of solution space, which in turn affect the further problem refinement in the concrete way. Research space is simply defined as bridging domains of designing, in which design dialogues of spatial thinking, visual expression, and factual assimilation take place, among a series of the problem-solution evolution. Research space, as a result, lies in the critical performance inclusive of searching relevant data, organizing and incorporating information into concepts, and experimenting configuration throughout design inquiry within the process, as shown in Table 1. From comparative, design activity findings of three

groups of participant designers, research space can be categorized into a series of three episodes in the design process of the co-development of problems-solutions:

1. Understanding criteria and formulating design goals.
2. Exploring possibilities: generating design proposals.
3. Examining reality.

These three design situations of research space are sequentially interrelated in the architectural-design process to enhance design inquiry as a "learning process of environmental creativity," which develops design activity from programmatic situations, conceptual ideas, conjectures, to concretely creative environments.

Research space generates new platforms of environmental design by way of integrating searched information with design ideas. Research space requires two-fold constituents; 1) searches for pertinent knowledge to problems, and 2) abilities to interpret new knowledge and synthesize a set of constructive forms—specific criteria and concepts, spatial systems, and symbolic configuration—immersed into design. In this way, research always cooperates with design methods/tools for transforming inputs to designing. Design tools allow a designer for simultaneously comprehending contexts and thinking in design considerations other than communication. In further study, design research collaboration with methods will be worthwhile to investigate in relation to problem-structuring and solving.

Table 1. Comparative research space in the framework of the co-development of problems-solutions.

3rd year students' research	5th year students' research	Professional designers' research	Serial research space
Understanding program, constraints, cases, and the site in relation to tasks to generate the project concept	Programmatic search: archival gathering, case analysis, constraints, site selection through setting up meta-problems Investigating design strategy: problem-framing and the schematic solution	Critically understanding tasks with design visions or challenges leading research: site insight, constraints, case analysis, and criteria to frame the concept and problems, including a project image	*Understanding criteria and formulating design goals*
Exploring schematic design: systems and activity arrangements related to the concept; discovery of spatial forms with ideas concerned information	Exploring conjectures with site conditions: spatial and formal configuration responsive to problems and set criteria combined with new data and ideas	Exploring design solutions: spatial organization and management Constructing design proposals: spatial and formal configuration and elements as well as processing relevant sets of data	*Exploring possibilities: generating design proposals*
Experimenting elements and details reflecting specific environmental symbols to concepts and design tasks	Experimenting critical, spatial volumes to present key concepts, agendas, users Discovering architectonic symbols related to place	Investigating critical elements suitable to problems Testing detail configuration, materials, construction methods manifesting design challenges	*Examining reality*

6. Conclusion: Design-Research Reintegration

The architectural-design process is a complex activity toward the environmental creation—an action inquiry between problem finding and solving. The pairing of problem space and solution space enables "research space" to be incorporated into design space. In other words, design research is able to integrate with the design process in a framework of the co-development of problems-solutions. Design thinking of developing a series of the design problem and solution relationships in design activity could make a designer to carry out collaborative research possible for both refining design problems and developing a comprehensive design proposal.

Research collaboration with the design process performs as inquiring modes of designing including abilities of associative interpretation of relevant knowledge toward design solutions. In realms of the architectural-design inquiry, research space plays roles as "operational bridging" within design space to transform design problems toward solutions. Research space functions as framing design problems and goals, exploring design potentials, and examining architectural clarity in the process of design development, respectively.

In design pedagogy, research in collaboration with design could be thus articulated in terms of the learning process. Systemic understanding of the collaborative design-research framework of the co-development of problems-solutions is requisite to the architectural-design discipline. Recognized as a discipline of the environmental creation, architecture is contingent to design methodology through which research helps to reinforce design frameworks. Research incorporating intensive design visions, moreover, becomes pivotal to direct problem-framing and appropriate design methods as much as design tools are required to synchronize intuitive ideas and empirical data into the coherent form. This study therefore proposes that design research can validly integrate with the design process as "strategizing mechanism" in the advance of architectural design, apparently related to accumulative skills.

For the future research, this study intensely suggests the comparative studies on design-research collaboration in a broad range of design practices between three different groups of undergraduate students on a senior level, graduate students, and research-based architects. Extensive design-research studies will progressively offer comprehensive understanding of critical factors and ramifications of the design-research paradigm.

Acknowledgement

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