Design Process-System and Methodology of Design Research

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Abstract. Studies have recognized the failure of the traditional design approach both in practice and in the studio. They showed that design problems today are too complex for the traditional approach to cope with and reflected a new interest in a better quality design services in order to meet the challenges of our time. In the mid-1970s and early 1980s, there has been a significant shift in focus within the field of design research towards the aim of creating a 'design discipline'. The problem, as will be discussed, is the lack of an integrated theory of design knowledge that can explicitly describe the design process in a coherent way. As a consequence, the traditional approach fails to operate systematically, in a disciplinary manner. Addressing this problem is the primary goal of the research study in the design process currently being conducted in the research-based master studio at Wollega University, Ethiopia. The research study seeks to make a contribution towards a disciplinary approach, through proper understanding the mechanism of knowledge development within design process systems. This is the task of the 'theory of design knowledge'. In this article the research project is introduced, and a model of the design process-system is developed in the studio as a research plan and a tool of design research at the same time. Based on data drawn from students' research projects, the theory of design knowledge is developed and empirically verified through the research project.

1. Introduction

Studies have recognized the failure of the traditional design approach both in practice and in the studio. They showed that design problems today are too complex for the traditional approach to cope with [1], they criticized the traditional approach for lacking objective knowledge [2] and expressed a new interest in a better quality design [3]. In the mid-1970s and early 1980s, there has been a significant shift in focus within the field of design research towards the aim of creating a 'design discipline', [4].

Although design is usually a result of integrated thinking, described as systems approach integrated response [5]. There is no design theory at present exists, as will be discussed latter, that can explicitly describe the mechanism of knowledge development and integration within the design process, which the study refers to by the term the 'design knowledge mechanism'. As a result, the traditional approach fails to operate systematically, in a disciplinary manner. Addressing this is the central issue in the research study in the design process, which is currently being conducted in the research-based master studio at Wollega University, Ethiopia.

The study seeks to make a contribution towards a disciplinary approach, through proper understanding the design knowledge mechanism, within design process systems. This is the task of the 'theory of design knowledge'. In this article a model of the 'design process-system' is developed in the studio as a methodology of design and as a tool for design research. The idea is not to impose a specific

methodology but rather to reproduce a systematic version of the implicit processes currently practiced in the studio, by the students themselves.

There are two research activities taking place side-by-side in this study where the proposed model of the design process-system will be used as a research plan in both. The first is the studio-based research undertaken by master students, in which the model of the design process-system will be experimented on and gradually improved through the implementation of the research project. It is a tool for knowledge development and integration, as will be discussed in detail later, through the knowledge produce and use processes within the design knowledge mechanism. The second is the education-based research project undertaken by a practicing researcher, the studio instructor. This latter research activity reflects on student's work and develops the 'theory of design knowledge' based on empirical data drawn from the inquiry in the studio.

2. The study problem and goals

Theorists have since the early days of the design methods movement recognized the dual nature of design and the need to balance creativity and rationality within the design process. Jones (1992) argued that rationality and creativity should co-exist instead of having one excludes the other. Since the1950s, writers have recognized these concepts as mutually interdependent and should not be considered as separate [6-8]. It has been noted that innovation requires both creativity and rationality, Owens (2006) argues that "A combination of science thinking and design thinking is better than either alone as a source of advice", [9].

Although the dual nature of design has long been appreciated, there is no theory has yet developed that could describe design in a coherent way. None of the two available theories, the rational problem-solving paradigm introduced by Simon [10] and the reflective practice paradigm proposed by Schon [11], could describe how the rational and the creative knowledge within the design process integrate. It has been suggested that these theories deal with different aspects of design. Therefore, their ability to describe the integration of the rational and creative aspects of the process is doubtful, [12].

It is often suggested in the literature that there is a conceived gap between the rational and the creative aspects of contemporary design. In good architecture, there should be no gap between the rational and the creative thinking. Some authors pointed out that "good design is usually an integrated response to a whole range of issues" including rationality and aesthetics. He argued that the best to identify good designers "is the ability to integrate and combine". The question is how does the knowledge mechanism within design process systems integrate the rational and the creative knowledge? Addressing this question is the core focus in the education-based research project in the studio. The research topic in the study is going to be a complex one. It is not only a question of understanding the way the knowledge mechanism operates, but explicitly describing the way it integrates knowledge is the main issue. This is going to be the task of the 'theory of design knowledge'.

The primary aim of this study is the development of the theory of design knowledge. To this end the study has two objectives: (a) to develop a model of the design process-system, as a research plan and a method of design research; and (b) to explore the design knowledge mechanism within the design process-system through the implementation of the different strategies of the studio-based research plan. The theory of design knowledge is initially presented as working hypothesis in the education-based research project where it is going to be developed and empirically verified. It aims to describe explicitly the design knowledge mechanism, structure and functions. The assumption of the study suggests that knowledge integration within design process systems can be systematically developed in an evolutionary manner by learning from the study of the precedents.

3. A proposed theory of design knowledge

This is a study of the process. Several studies showed different types of design knowledge and different ways of knowledge acquisition [4, 12, 13]. However, studying the process requires not only studying the different types of knowledge and the different ways of knowing, but more importantly the design knowledge mechanism within design process-systems should receive more attention, [14].

Although studies showed that design is usually a result of integrated thinking. There is no theory has yet developed, as already mentioned, that could describe explicitly the way the rational and the creative knowledge within the design process integrate. The reason as often mentioned in the literature is the indetermination of design problems. However, designers manage somehow to overcome the indetermination of design problems and to blend the rational and creative knowledge [15]. In the absence of a coherent theory of design knowledge, this claim remains an implicit activity taking place through the conventional design practices. As a result, we don't know how the design knowledge mechanism works.

However, in the 1980s, design methodologists claimed that even though the property of design problems is indeterminate, the approach to indeterminate problems can be scientific, [1, 16]. In consistency with this important thinking the study tries is to demonstrate that the integration of the rational and creative knowledge can be systematically captured and explicitly described. It proposes the theory of design knowledge, which aims to describe explicitly the functions of the design knowledge mechanism as actually practiced by the master students in the studio-based research project.

Observation indicates that balanced integration in architecture design has throughout history been associated with the evolution of knowledge from the design experiences of the past. Designs that developed from old ideas are normally identified with balanced integration. Similar views were expressed by Grout and Wang [17]. They noted that research has been integral part of design throughout architecture history. The implication is that good architecture throughout history, which usually shows a remarkable balanced integration, has been the result of evolution by learning from the experiences of the past. Unlike the contemporary stylist architecture, which usually is a result of concern with novelty the rational problem solving by contrast is more frequently a result of evolution from the traditions of architecture design. Today, it is not uncommon that architects seek to overcome the indetermination of design problems by finding a determinate area in the creative part of design knowledge and trying to widen that part by studying and learning from the design experiences of the past, [14].

4. The design context

Degree programs in architecture research usually offer multiple areas of specialization or emphasis. In the master program research is undertaken within a specific context deriving from a variety of contemporary issues of local and global concern such as environmentally friendly sustainable design and smart-tech-integrated design. It is called such design interest, motivations. He showed that designers have their own motivations, reasons that direct their design and described that as sets of beliefs, values and attitudes. In the master studio, these ideals can certainly be seen as a set of guiding principles as suggested.

A newly discovered interest in design within specific contexts has emerged from the students themselves without interference from the instructor, whose contribution was no more than assisting in documentation and abstraction. The idea has encouraged a non-conventional discussion, innovative thinking and raised many questions in the studio. The discussion shows that students' growing interest in design within specific non-conventional contexts has led to a remarkable change in focus away from the end product to the wider design process. One significant result of the change in focus in the studio is the rising awareness that the relationship between design problems and problem solution can be more clearly understood on basis of the interdependent nature of their rational and creative knowledge content.

The interdependent characteristic of the rational and the creative knowledge was described. They showed the interdependence of the rational and the creative knowledge in two ways. First, the rational approach is based on the 'knowing that' knowledge, whereas the creative approach relies on both the 'knowing that' and the 'knowing how' knowledge. Second, the 'knowing that' knowledge depends on the 'knowing how' knowledge [5]. Understanding the interdependent relationship of the rational and the interpretive design knowledge showed, makes it easy to understand the complementary nature of design problems and solutions on the same basis.

It has been suggested that central in modern design thinking is that design problems and problem solution are seen as emerging together, rather than one following upon the other (Lawson, 2005). The reason as often mentioned in the literature is that their rational and creative knowledge contents are mutually interdependent. The implication is that the integration of the rational and the creative knowledge is a process. Similar to the case of design problems and problem solutions, knowledge integration is not a matter of developing the rational knowledge separately and then trying to tailor a creative response that fits. This argument brings the study closer to the research question: How does the knowledge mechanism integrate the rational and the creative design knowledge components? [14].

Exploring the way problems and problem solutions emerge together through the processes of the research project can help understanding how the knowledge mechanism integrates knowledge. The assumption suggests that learning about knowledge integration can be objectively acquired by studying the design experiences of the past. The validity of this assumption will be verified in the research project by examining the complimentary role of the rational and the creative design processes in the co-emergence of problems and problem solutions.

The last section of the present article is devoted to the empirical study based on the master students design research, which is referred to in this study by the term the 'research project'. It will examine the way students working within specific design contexts manage to overcome the indetermination of design problems and to integrate the rational and the creative knowledge systematically.

5. The research project

A model of the design process-system has been developed in the studio, as already mentioned. It is intended to replace the implicit practices currently being used in the studio with an explicit version, which embodies the same techniques and strategies that already existed. The model has been practically developed by the master students and edited for the purposes of this study.

There are two research activities taking place side-by-side in this study. The proposed model of the design process-system will be used as a research plan in both (Table: 1). The first is the studio-based research undertaken by master students, in which the model acts as a methodology of research and design. It is a tool for the development of knowledge through the knowledge produce and use processes within the knowledge development mechanism as will be discussed in detail through the coming sections of the article. The second is the education-based research project undertaken by a practicing researcher, the studio instructor. This latter research activity will reflect on students' work and develop the theory of design knowledge, which aims to describe the structure and functions of the design knowledge mechanism.

The dual research functions of the model show that the design process-system approach is in this case a new form of the education-based research, which was originally suggested by Johansson (2009). The education-based research method means that research is based on studio practices, where research is undertaken by practicing researchers with students' research-based studio projects is the core activity. This combined education-based research and research-based studio, is a novel framework introduced and applied in this study as a tool for innovative design research. The interface between the two research activities served by the model is the inquiry in the education-based research project, which discusses and analyzes students' research work, and verifies the theory of design knowledge.

Architecture design research can be undertaken for different purposes and in different contexts. According to Bashier [14] three types of design research are identified in the literature, they are: research for design, research through design and research about design (Frankel and Racine, 2010). The studio-based research projects, undertaken by students, is concerned with the first two types namely research for design, and research through design. In which the emphasis is on the development of knowledge rather than design solution.

'Research for design' encompasses those activities or projects that aid and support design. Such projects may also involve designing but their main goal is to inform or support the design process [18].

In his book Design Research, Downton calls this area "research to enable design". This research area provides the information, implications, and data that designers can apply to achieve an end-result in their design projects, [19].

Table 1. A concise model of design process-systems

No	Processes strategies	Activities	
		Producing knowledge	Using knowledge
1	Design proposal	• define **design problem**, articulate **problem-solving approach**; • undertake **background preparatory research in the literature;** • articulate **design proposal, design criteria;** • Identify **research plan.**	
2	Design theories	• review the **literature**, analyze, evaluate **design documents;** • formulate **design theory**; • **case-study**; • verify and refine **theory of design knowledge.**	
3	Design concepts		• generate **multiple concept options**, • select **best concept** according to criteria; refine **design proposal;** • **discussion and conclusions.**

'Research through design' involves disciplinary specific practices where design is itself utilized as a research practice, constituting both the means and outcome. [18]. In this approach, the emphasis is on the research objective of creating design knowledge, not the solution. The most important aspect of research through design is that it seeks to provide an explanation or theory within a broader context. It may combine the practice-based research approach of practitioners with reflection on a research question that "is not restricted to the product on which research is being conducted". (Frankel and Racine, 2010)

Findeli, according to Frankel and Racine [19], differentiates the two design research approaches by associating "through design" with theory and "for design" with practice. The master studio is interested in the type of research, which forms an integral component of the design process during defining the design problem and finding the problem solving approach and the study of the precedents. This type of research provides knowledge, which can be used repeatedly to inform a widened domain across the design process in other or similar design problems. Therefore, it is a technique which combines both research for and research through design approaches.

Within this broad framework, the master students are free to choose either 'research for design' or 'research through design' methodology according to what best serves their project objectives. Although most students claimed, according to the opinion test within the research project, that 'design through research' approach represents their research orientation more. It is noted that many have used a combination of the two approaches sometimes with more emphasis on one or the other, it is difficult to tell. However, both approaches use the same model of the design process-system, [14].

The second research activity within the study is the education-based research project undertaken by the studio instructor. This research activity is concerned with the third research type identified by Frankel and Racine [19] as 'research about design'. In this study research about design takes the form of inquiry in students studio-based research work, investigating the design process-model and the ways

of explicit documentation of research outcomes, strategies techniques. The education-based research is an inquiry in methods of design research with reference to the traditional societies. The emphasis is on the formulation of design research problems within context of global and local areas of concern that are relevant to the development these societies. Consideration is given to areas of design research prioritization away from the normal singular designer interest to collective decision-making. Another area of interest is learning from the design experience of the past as a rational method to overcome the indetermination of design problems.

Lawson provided a concise history of the development of research methodology in design since 1980s. He showed that most of what had been written by then was not based on empirical research. "Many early writers described not a design process they had observed, but one they believed logically must take place". Later research in design methodology put the designer in a laboratory environment so as to observe the process under more objective and rigorous empirical conditions. Lawson described several other developments in design research methodologies including the more recent simple technique of asking designers to tell the researcher what they do either by interviewing them or by reading what they have written about their process. In his survey Lawson discussed the different research methodologies and identified the merits or the weaknesses of each one of them.

In the empirical study conducted in the master studio, two methodologies mentioned in Lawson's list are used. Firstly, observing and reporting empirical evidence from students' research work in the studio. Secondly, analysing students' own account of the process. They were asked to reflect on their experience in the design research project by responding to a questionnaire. A questionnaire is aimed to survey students' attitude in relation to the development of the design process-system was presented to them after the task is ended. The questionnaire includes 14 questions, which requested students to reflect on the various aspects of the design process. The respondent students' feedback beside the observation in the studio will constitute the primary source of data in the research project.

6. The Knowledge development mechanism

The model of the design process-system has been developed and used in the studio as a framework for the development of knowledge. Within this framework the concept of knowledge development mechanism operates as observed in the studio, through three processing 'strategies': the first two strategies are concerned with knowledge produce, including the articulation of design proposals and the formulation of design theories. The third strategy is focused on using the rational knowledge produced in the first two strategies to refine the design proposal and to generate the concept.

The goal of design research, as defined by Cross [4], has to be "the development, articulation and communication of design knowledge". He showed three sources researchers should seek design knowledge from: "people, processes and products". The knowledge development mechanism within the research project is concerned with the development of knowledge drawn from three sources too: the literature, processes and buildings. The literature is the first source of design knowledge in the master research-based studio and in any design practice. Therefore, one immediate subject in the research project is literature review.

The literature review is a very important part of the design process that is essential not only at the beginning of the process but throughout [17]. It is a primary source of knowledge, which contribute, beside others sources as already shown, to the development of knowledge through all three strategies of the knowledge development mechanism. The literature review in this study is explored in such a way as to enable the topic of inquiry to be competently defined and addressed, as Grout and Wang [17] suggested. The literature review in the research project is intended to address the research topic of inquiry throughout the different phases of its development. This is evident in the developed model of design process-system where literature review is practiced in each one of the three strategies in a different way.

Design knowledge is acquired secondly from the study of the processes. Although traditional design is normally a crafts approach that rarely applies explicit methods, it would be foolish, as Cross rightly pointed out, to disregard or overlook the knowledge that comes as a result simply because it has not

been made explicit yet. That is the task of the theory of design knowledge in this study. In this study a major area of research is focused on the design-process system including the knowledge development mechanism, as will be discussed in the following sections, and the three processing strategies within.

The third source of knowledge is found in buildings. In the words of Cross [4] much of everyday design work entails the use of precedents or previous exemplars because the exemplars actually contain knowledge of what the product should be. Studying and learning from the experience of the past is the central issue in systematic knowledge integration in this study.

7. The design proposal articulation process

Design proposal as observed in the studio is the first strategy within the knowledge development mechanism, which is concerned with the articulation of design-problem-solution emerging together. The terms problem solving and problem solution should not be confused. Problem solution normally refers to the end product, which is reached through a problem solving process. In this study, the term design proposal means a comprehensive statement, which describes the problem solving process through which the problem solution can be reached. It is a dual process, which leads to defining the design problem and problem solution through a non-linear problem solving process.

The design proposal as developed in the studio takes the form of a written statement with diagram illustrations, which serves several purposes. The document represents a comprehensive programming research, which has several goals and ways to achieve goals. It suggests the area of research inquiry, scope of the literature review and formulates the research questions. In addition, the design proposal also provides the basis upon which design theory develops, and lays out a theoretical foundation for concept generation.

Defining design problem and problem solution involves research in two areas conducted almost in parallel. They are:
  a) defining the design problem with emphasis on a specific pre-determined design context. Different research methods are used, including interviewing all people concerned in addition to the use of questionnaires;
  b) identifying problem solution. Although, identifying problem solution normally relies on the knowledge from searching the literature particularly design documents, but sometimes relies on experience.

The inquiry of the design proposal was aided by background preparatory research in the literature. The study finds the background review of the literature is necessary at this early stage of the research or design, for obvious reasons. The literature review in this context is part of the pre-research investigation, which aims to develop the design-problem-solution scenario and to articulate a design proposal. It is different from the literature review proper, which will be conducted within the research project and has different aims as will be discussed latter. The articulation of the design-problem-solution together as a proposal will have to be further developed through the following two stages of the design process.

8. The design theories formulation process

The second strategy of the knowledge development mechanism is normally concerned with the study of the precedents and the formulation of design theory. The purpose of the inquiry as observed in the studio is to act both as a source of knowledge and design examples. Through extensive analysis and evaluation of the precedents students were able to explore the design experiences of the past and to discover design norms. Two types of research methods have been involved: literature review and case-study research. The first is an exploratory research in the literature, which aims to define and address the design problem and to suggest design theory including possible solutions and the relevant problem solving approaches. The second research method is focused on conducting empirical inquiry in case study research to verify the suggested design theory.

Architecture design normally responds to external influences and rules (norms), which can be discovered, identified and described using systematic and deductive processes. In the master studio, research in the precedents normally begins with extensive literature review. In theory formulation

strategy the main literature review is part of the studio-based research project which is concerned with providing a theoretical background of the inquiry. The type of research the master studio is interested in, as already stated, is an approach that combines design for and through research, which serves the needs of the student in his capacity as a researcher and as a designer at the same time. Both the researcher and the designer practice literature review to discover theory. Whereas, the researcher aims to describe, test or expand existing theory; the designer uses design theory in a different way as to form basis for the development of a new design.

Students have searched several types of literature including the conceptual literature concerning theories in the topic of inquiry; previous research and academic writings such as thesis; the empirical literature consisting of studies made earlier which are similar to the one proposed; in addition to design documents. When searching design documents, students have tried to get familiarized with the type of design problem by exploring the traditions from the general pool of design culture. They have examined the design problems under investigation trying to discover the basis of decision-making, design-problem-solution determinant factors as well as the possible alternative design component relationship. The outcome of the literature review is the knowledge which has enabled students to identify the common practices, to describe the principles followed in designing specific types of buildings in the past and to formulate design theories or to identify a possible design model to follow.

Document-based research is best be compared with confirmatory knowledge drawn from empirical case-study research to add more knowledge as to how well a design functions. The case study is essentially an intensive investigation of the particular unit under consideration, which is analyzed in its relationship to the other units within the cluster of units within the total space pattern. Perhaps the first thing students start with in studying the precedents is examining space patterns, trying to reveal the reasoning behind spatial relationships.

It is suggested that case-study is a research method that is used in practice-based research known as research through Design, which is associated with theory formulation. It is a form of applied research that is designed from the start to apply its findings- design theories- to the design problem and generate design concepts [19]. Design theory can be derived by generalization from past solutions. One relevant form of design theory was suggested by Heylighen & Neuckermans [20], is the one they refer to as *'types'* of architecture. They regard *types* of architecture as generalization of design solutions that have shown to be satisfactory in the past and may be reliably used as models for future design.

It has been a common practice in the master studio that students build design theories from the basic functional units. It is the study of component-systems' relationship involving: the characteristics of the basic functional units, the way they are articulated and clustered within structures. The focus is on studying the characteristics of the various types of basic interior spaces, the factors that determine their characteristics and the impact these factors have on the spatial organization within component-systems. They aim to establish rules and the basic principles that govern space arrangement and adjacency relationships such as those on basis of circulation.

Case-study research seeks to study and evaluate the precedents to provide rational explanation. It will attempt to establish causal links and relationships between the different elements of the design and relate the whole to a particular theory, context or practice [17]. One example from master students' work has investigated the use of digital communication technology in hospital design in Ethiopia. The study focused on defining the criteria involved in the integration of digital communication technology and space layout. The student began reviewing the literature by examining design documents in order to identify measures of better quality health care facility. Patient satisfaction, information flow and the efficiency of medical services delivery were identified as quality indicators, which were used as criteria for judging case-study and as a guide for design.

Case studies can be used as Groat and Wang [17] suggested, "As illustrative examples high-lighting larger abstract principles, for example as case studies to illustrate general principles of sustainable design". One student observes that sustainable building is not a new practice Ethiopia. It is centuries old tradition as evident in vernacular architecture, which is still practiced in many parts of the country today.

He calls on designers to learn from their ancient traditions and to adapt the knowledge to present time need in order to improve sustainability standards in modern design.

9. The design concepts generation process

The third strategy within the knowledge development mechanism is the one concerned with generating design concepts. The traditional design approach usually relies on implicit knowledge and sketching in the development of space planning and generating three dimensional forms. In the master class, it is noted that students take a distinctly different approach, which seems to emerge from the growing interest in the design process and the changing nature of the design product. The process begins with a written statement, which shows several design concepts or ideas, describes the rationale that lead to such concepts and also the reasoning that supports decision-making in each case. The written statement is supported by sketching to illustrate each of the various proposals showing design planning and the creative embodiment of design proposal into a three dimensional context. It is noted that the master student's sketching is different in that it takes the form of a diagrammatic illustration, which aims to demonstrate spatial relationships instead of the prevailing artistic drawings in the conventional studio. The process leads to the selection of the best proposal according to criteria.

Concepts, similar to design theories, are concerned with design component-systems' relationship. It has been suggested that concepts mean the "Knowledge about the way in which components are integrated and linked together in a coherent whole" Heylighen & Neuckermans [20]. The study differentiates between design theories and design concepts on basis of existing or new components' relationship. Therefore, it is possible to identify theories with descriptive knowledge of older designs and concepts with prescriptive knowledge of new ideas.

Another way of looking at the difference between the meaning of theories and concepts is by describing the relationship between the parts and the whole. While, design theories describe the way the parts are meaningfully articulated within the whole, concepts prescribe the way the parts ought to be integrated into a coherent whole. Theory formulation results from discovering the laws that control the relationship between the parts and between the parts and the whole. In concept generation by contrast the focus is on inventing new relationships prescribing the way the parts ought to be integrated within whole. Therefore, it is an activity that involves new design thinking of the way in which the parts may be creatively articulated within the whole.

Although concept generation theoretically is the use of the rational knowledge provided in the first two strategies, a return back to the literature is sometimes necessary. Here, the return to the literature focuses on document research, which architects often use as a source of inspiration or evolution from the design experience of the past. It has been noted that while these designs from the past are sources of knowledge about every aspect of design, they can serve as models for the spatial distribution of functions [17].

Most students in the master studio used the case study as source of knowledge and also source of inspiration or as design example to follow. Studying and learning from the precedents is the practice which has been generally used by all master students. It is an activity, which involves using older models as generators. It involves re-inventing older relationships and modifying the model to suite modern technology and future needs as seen in the transformational evolution method of concept generation. Although, concept generation in most cases is based on a model drawn from the literature but using experimented designs, which have previously proved adequate, has often been a reliable option.

Some authors offered a very useful conceptualization of 'creativity', from which we draw insight for understanding creativity in architecture design. He suggested "A simple definition is that creativity is the ability to imagine or invent something new". However, "Creativity is not the ability to create out of nothing, but the ability to generate new ideas by combining, changing, or reapplying existing ideas." he argues. In architecture, generally speaking, there is no design that is entirely a new design. Every design emerges somehow from the pool of architecture traditions, which is available for future designs to draw from. It was suggested that creative people generally work hard and continually to improve ideas and solutions, by making gradual alterations and refinements to their works. He mentioned that several

methods have been identified for producing creative results including: evolution, synthesis, revolution, reapplication, changing direction. He explained "Evolution is the method of incremental improvement. New ideas stem from other ideas, new solutions from previous ones, the new ones slightly improved over the old ones."

It is noted that all the methods compiled for producing creative results share learning from the precedents as source of knowledge. Architects similarly tend to develop a variety of concept generation methods, all of which seem to be based on learning from the design experience of the past, including: 'Evolution' is the method used in learning from the design experience of the past. Architects often build on the experience of the past, and it is quite normal for architects in practice to develop design in evolutionary mode. They would be concerned with discovering the principles of space arrangement, the way space is articulated within forms, and how the form evolves as a logical result of the articulation of space within them. This strategy, according to Heylighen and Neuckermans [20], is referred to as '*analogy*'. When using analogy, architects call on existing forms or use form-generators as a point of departure. Glazunov (2012) commented that the evolutionary method of creativity reminds us of the popular principle: Every problem that has been solved can be solved again in a better way.

'Inspiration' is another relevant example of the methods used by architects as concept generation, which is described as most popular method among architects. Inspiration is to draw insight from the study of the precedents. It is having been noted that architects often seem to seek insight, sometimes called inspiration, from the work of others or from their own work. Heylighen & Neuckermans [20] identify '*cases*' as a method of concept knowledge generation. According to the writers '*Cases*' or what might be termed as case-study are concrete projects from the past, which they described as the "(re-) use of concrete cases". "Architects seem to draw a considerable amount of design knowledge from concrete design cases, designed by others or by themselves", [20].

10. Conclusions: The theory of design knowledge

Addressing the research question is the task of the 'theory of design knowledge'. Its main goal is to describe explicitly the way the knowledge mechanism within the design process-system operates and integrates the rational and the interpretive knowledge. Throughout the research project the study has focused on collecting evidence to demonstrate how the approach to the indeterminate problems can be scientific. The research project shows three methods which students use in order to overcome the indetermination of design problems and to integrate the rational and the interpretive knowledge systematically.

The first is by finding a determinate area within the part of the design problem knowledge, which is considered indeterminate and trying to widen this part. Observation in the studio suggests that both the rational and the creative knowledge, to some extent, can both be acquired by research. It is noticed that widening the determinate part of design problems systematically, is possible by learning from the study of the precedents. The research project has collected adequate evidence from students' work which clearly supports the assumption that indeterminate knowledge can be transformed largely by learning from the design experiences of the past. Although older designs from the past are sources of knowledge about every aspect of design, they can serve as models for the spatial distribution of functions [17]. Most of the master class students have used the precedents as source of knowledge and as design model to follow. They develop new design concepts by gradually improving older problem solving ideas and adapting them to modern technology and future needs.

The second method students use to achieve knowledge integration systematically comes from the shift in focus away from the end product. As a result, students are not consciously concerned with a gap between the rational and the creative knowledge and, consequently not worried about how to bridge such a gap. The change in the definition of design as a process has led students to focus less on the end product as a form making and more on the process as problem solving. Problem solving as now practiced in the studio is not focused on designing single individualist buildings as much as on developing innovative theories and design principles for a wider range of design problems of community need.

The emerging interest among students in design within specific non-conventional contexts deriving from broad national and societal development goals has become a motivation which led to a noted departure from the common obsession with design as form-making to a new objectively driven focus on design as a problem solving process. Focusing on the process has led to understanding the interdependent relationship between the integration of knowledge and the co-emergence of design problems and problem solution, and consequently led students to seek an objective approach to the development of creative knowledge and concept generation.

The third way students use to blend the rational and the interpretive knowledge systematically, is dependent on the objective or subjective interpretation of design problems. Knowledge use is the activity concerned with the type of knowledge described as partly indeterminate in which normally both the possible interpretation of the design problem and selection of possible suitable solution of the problem, can be made only on the basis of proposals made by the designer, as Dorst [15] argued.

Dorst (2003) suggested that the indeterminate knowledge can be reduced considerably depending on the architect's objective or subjective interpretation of the design problem. Based on Gadamer [21], he suggested that if objective interpretation is applied to design we can see that the decision whether a part of a design activity will involve 'objective' or 'subjective' interpretation ultimately rests with the designer working on the design problem, [15]. In the master class where students are engaged in design within a specific context rooted in the national and community development goals, there is a vested interest, as students work has shown, in objectifying the design goals and decision-making. In such a case in which the objective interpretation of design problems plays a major role, as the research project has demonstrated, the possibility for a substantial elimination of subjectivity is quite high and consequently design problems can be considered largely determinate.

The above analysis of the three methods used in the studio to overcome the indetermination of design problems, has shown how students manage to integrate the rational and the creative knowledge systematically. In conclusion the article demonstrated the way the theory of design knowledge has empirically addressed the research question, and how it has explicitly described knowledge integration within design process-systems.

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