An analysis of 'problem framing' activities in digital versus paper media

Gao Song[1] and Kvan, Thomas[2]
Department of Architecture, the University of Hong Kong

Abstract

Architectural design is described in part as the solving of ill-defined or wicked problems. In these activities, designers are not only simply given well-stated problems but also need to find and formulate problems. This process is called as 'problem framing'. Paper media have been for many years the design tools used by designers to help them engage, and hence frame, problems. Computer technologies have gained prominence in design processes but have typically been used in discrete problem solving processes or in presentation. It has been stated that problem exploration is more difficult using a computer tool. This attitude has influenced the teaching and use of computers in architectural education. The purpose of this study is to understand how digital and paper media are used respectively in 'problem framing' activities in support of students' design learning. This paper reports a pilot laboratory study to test the validity of a proposed coding scheme comparing design activities using digital and paper media and report initial results of the research. Through this research we wish to gain insight of ways in which students engage in 'problem framing' activities using different media and suggest ways in which digital media might better support problem framing activities.

Keywords: Problem framing; digital design; protocol analysis; studio teaching

1. Introduction

Architectural design is the activity of conceiving and planning an artificial world (Buchanan 1995). Architectural design problems are categorized variously as well defined, ill defined or wicked (Rowe 1987 : 40), reflecting the extent to which their solutions are immediately apparent. There are no definitive boundaries of ill-defined and wicked problems (Rowe 1987); hence a design brief can not fully describe problems. Designers view design problems assuming 'some ill-definedness in the goals, initial conditions or allowable transformations' (Thomas and Carroll 1984). Before problem-solving designers must frame problems to enable exploration of a distinct problem space. In order to approach a design problem the students must learn how to identify the problem to be solved, attempt solutions and decide if these are appropriate. These activities are called as 'problem framing' (Schön 1984). Schön (1985: 32-52) has referred to them as 'reflective conversation within the situation': *naming, framing, moving and reflecting*. Schön (1985) analysed the activities of 'problem framing' happened in design studio on observation of Quist (a master) and Petra (a student). The design problem Petra faced was to try to fit the shape of the building she designed to the slope of the site, but she failed, which led her feeling 'stuck'. Quist reframes this problem by beginning with a principle that "coherence must be given to the site in the form of a geometry" (Schön 1985: 36). Quist implied Petra could try a new geometry by "making the knowing the violation of the initial geometry" (Schön 1985:36) as he then demonstrated by means of a series of sketches. These sketches illustrated his way of reframing this problem. Quist continued identifying ("naming") new design problems (environment problem, sunlight

[1] Gao Song, Miss
[2] Kvan, Thomas, Professor

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problem, circulation problem, etc.), working his way through stages described by Schön as "framing, moving, and reflecting", suggesting a cyclical design process that steps through these three stages. Schön (1988) identified 'problem framing' as the means for a designer to identify and isolate a design problem such that it can then be solved. In framing, the designer will "set its boundaries, select particular things and relations for attention, and impose on the situation a coherence that guides subsequent moves" (Schön 1988: 182). An analysis of the process by which Quist framed the first design problem in Schön's example might help us understand 'problem framing' activities:

Examples of 'problem framing'		**An example of design problem**
"Set its boundaries"	:	"A principle" — 'starting from a geometry form'
"Select particular things and relations for attention"	:	"L-shaped classrooms and orientation of them, etc."

Quist used 'drawing and talking' — the language of designing — to teach Petra how he framed design problems and experimented with them. In Schön's words "Quist has reflected critically on Petra's framing of the problem. He has conducted an on-the-spot drawing experiment in reframing the problem. And, in the process, he has conducted a reflective conversation with the materials of the design situation" (Schön 1985: 51). Therefore the goals of architectural education are not only to teach students how to solve problems, but also to teach them how to identify or 'frame' problems.

Paper media have been regarded as useful design tools to help designers frame problems. Schön (1984) shows that a designer produces drawings or sketches to experiment and test his/her ideas, to allow the situation to 'talk back' to him/her. Cross (2001:90) points the sketching could help designers to 'find unintended consequences, the surprises that keep the design exploration going'. Digital media have established themselves as new design tools, greatly affecting design practice and education. At the moment, however, they are intensively used for the purposes of problem solving and presentation, which in turn influences architectural education. Some scholars suggest digital media are inhibiting designers' communication between mind and hand, hence interrupting the 'framing' activities (Corona-Martinez and Quantrill 2003). Of interest to us is the question whether the application of digital media changes the extent to which students are undertaking design framing activities.

2 'Problem framing'

Many scholars have attempted to describe the architectural design process (Schön 1985; Rowe 1987; Mitchell 1994; Buchanan 1995; Simon 1996; Cross 2001). Most concur that design involves, to some extent, a process in which a designer must transform wicked design problems into well defined to make the wicked problems to be solved. Rowe (1987) notes that there are two kinds of knowledge: 'procedural knowledge'— 'know how' (Simon 1996) and 'substantive knowledge' ---'know that' (Schön 1983), and points out both of them are intertwined and related during designing. 'The two facets of the problem are clearly intertwined. Without social purpose it is difficult to imagine how a broad understanding of and meaning for architecture can be established. On the other hand, without engagement it is difficult to see how architecture can be conveyed in the cultural mainstream, even with a strong sense of purpose' (Rowe 1987:201). In his description of Simon's 'know how', he distinguishes such design activities as 'purposefully planning', while Schön's 'know that' is the design activities of 'engagedly conveying'. He emphasizes the design ability of 'organizing principles and constraints' is the answer to use both knowledge to solving wicked problems (Rowe 1987:115).

Although Mitchell (1994) doesn't talk about wicked problem, he categorizes design as a kind of functional interpretation, such as "in order to produce and justify designs that not only have desired formal properties but also satisfy specified practical requirements, a designer must be able to infer the functions of architectural elements and compositions from their formal properties" (Mitchell 1994:210). In his view the duty of an architect is bringing order to the world (Mitchell 1994:1). For him therefore "a design problem exists when you want something but cannot immediately see how to get it: intellectual effort is find a solution … the task is to manipulate the design world to produce such a state and to demonstrate that this state satisfies the predicates of the formulation" (Mitchell 1994:64). Here we can see that Mitchell's approach is a design activity that is 'planned' to satisfy functional requirements and the form of compositions by utilizing design rules such as types and vocabularies. The similar description of the procedure of 'manipulation' or 'planning' can be seen in Simon's analysis 'heuristic search' (Simon 1996). He regards the power of heuristic search can reduce the sizes of the problem spaces by using the artificial intelligence of computer, and points out 'not only are such

systems capable of discovering new concepts but also they can plan sequences of experiments, postulate reaction paths for complex chemical reaction, induce rules for interpreting data from mass spectrogram analysis, and enlarge the state space of a system to accommodate variables that are not directly observable' (Simon 1996:20). Simon therefore believes that 'heuristic search' is a key issue to solve ill-defined problems.

Rowe's 'organizing principles and constraints', Mitchell's 'functional order', and Simon's 'heuristic search' focus on the activity of 'planning'. We recognize that these parts are essential for designers to solving wicked problems, however, other than this is there anything else existing? Buchanan (1995:17) points out that Simon's procedure has 'planning' without 'conceiving', and claims that although "Simon has in distinguishing the artificial as a domain of humanmade products different from object created by natural process, he does not capture the radical sense in which designers explore the essence of what the artificial may be in human experience". It is interesting for us to note that the above three studies do not raise an important facet of architectural design or others kinds of design: bringing 'new' and 'original' things into the production. Buchanan (1995) claims architectural design is the activity of conceiving and planning an artificial world, directing the solution of wicked problems. After analyzing four design areas, such as symbolic and visual communication, material object, activities and organized services, and complex systems or environments, he identifies the four areas are related each other in that 'the design professions primary concern begins in one area, but innovation comes when the initial selection is repositioned at another point in the framework, raising new question and ideas.' (Buchanan 1995: 9). Therefore the four areas constitute 'placements', and by using it a designer can 'discover or invent a working hypothesis', since 'placements have the sources of new ideas and possibilities when applied to problems in concrete circumstances' (Buchanan 1995: 11). Buchanan points out two important issues in solving wicked problem: first is to conceive a new problem: 'a working hypothesis', second is to the knowledge of planning cross-disciplines, the 'placements', to relate the new thing. After observing twenty minutes' protocol happened in a design studio, Schön (1985) calls this kind of design activity as 'problem framing', which is involved in a circular design process including 'framing, moving, and reflecting'. 'Framing' refers to identify a new design problem or idea; 'moving' refers to produce a tentative solution of this idea or problem; 'reflecting' refers to evaluate this solution. Schön (1988:183) describes the two terms: 'naming' and 'moving' as 'set its boundaries, select particular things and relations for attention' and 'impose on the situation a coherence that guides subsequent moves', while describes the term: 'reflecting' as 'allow the situation to back talk to him' that is to reflect on the 'framing' and 'moving', leading to reframe, retest and re-evaluate. Buchanan's viewpoint is similar with Schön's 'reflection in action': 'framing' and 'moving'. Buchanan points out the knowledge of design that Schön does not explain, while Schön's 'reflection on action' is what Buchanan lacks. Cross (1995) describes the design process as a cycle involving problem exploration, trial, test & evaluation. Adams, Turns, et al. (2003) regard problems are actually involved in an iterative design process: problem scoping, developing alternative solution, project realization and find that senior students engage in this cycle more frequently than junior students.

Goldschmidt (1989) describes 'problem representation' as a process of acquiring problems from given information. She finds that problem representation plays an essential role during the process of designing. Kolodner and Wills (1996) suggest that 'problem reformulation' could prevent designers from being trapped into 'default assumptions about the constraints of the problem' and assist designers to create new criteria and constrains. Cross and Cross (1998) claim that 'problem framing' is to 'framing the problem in a distinctive and challenge way' and notice that it an important aspect of design strategy adopted by outstanding expert designers. Cross (1999) explains design as exploration since designers accept design brief as a part of 'unknown territory' and start to explore and discover something new rather than to return with something already existing. 'Problem framing' plays an important role in design process and good designers can intelligently frame problems (Cross 1999). Cross (2001) points out that the activities of 'problem framing' could prevent students from 'fixation' on an early concept, meanwhile 'frames' can clearly be negative conceptual structures, when they are inappropriate 'fixation', as well as positive, creative structures'. Kavakli and Gero (2001) find that there are obvious differences between the design activities of experts and novices, largely in 'problem framing' activities. Some countries have adopted performance based codes rather than prescriptive codes. 'This can give architects more freedom to develop creative structures, bypassing inhibitions imposed by prescriptive codes'(Bowman 2002). The emergence of performance-based code probably requires architectural educators to pay more attention on students' ability of framing problems, not just solving problems. Geol and Pirolli (1992) explain 'problem framing' as 'problem structuring': because of the ill-defined problems designers need to 'to establish and transform problem parameters' before the starting of

problem solving. Geol and Pirolli (1992) indicate that although 'problem structuring' activities occur mainly at the beginning of design project, they reoccur periodically as needed during the process of designing.

'**Problem framing**' therefore is that designers use their cross-disciplined knowledge to explore something 'new' and 'original', and is an essential part of the design process of '*framing, moving, and reflecting*'. Only engaging in this design process, designers can frame design problems efficiently and intelligently.

2.1 'Problem framing' and design tools

Deleuze's idea of folding is more radical than origami, because it contains no narrative, linear sequence; rather, in terms of traditional vision, it contains a quality of unseen. … that is , it can be considered to be effective; it functions, it shelters, it is meaningful, it frames, it is aesthetic. Folding also constitutes a move from effective to affective space … that are more than reason, meaning and function.

In Visions' Unfolding: architecture in the age of electronic media,
Peter Esienman 1996:559

Sketching is usually regarded as a design tool to help designers engage in framing design problems (Cross 2001). Schön and Wiggins (1992) suggest 'reflective conversation with materials' as 'an interaction of designing and discovery' as a potential of sketching, which could assist designers to find surprised or unintended results. Goel (1995) states two functions of sketching: vertical transformation and lateral transformation. The 'lateral transformation' could assist designers to produce new ideas from existing drawing. Goldschmidt (1991) explores the reasoning of sketching used by designers, and finds dialectics of sketching, a pattern of design activities when designers engage in sketching. These characteristics of sketching are regarded as main reasoning to represent design problems.

In the past, conventional CAD systems are never designed to be used in conceptual design stages because of the precision, therefore they are regarded as interrupting designers' 'problem framing' and largely used as problem solving and presentation tools. New software is being developed especially for design to bridge the gap between primitive ideation and design development' (Corona-Martinez and Quantrill 2003:177). Computer aided conceptual design (CACD) systems and Internet technology for example, are facilitating this change. Compared to paper media some advantages are provided by these systems such as faster generation of design alternatives, provides a platform for better communication and evaluation of these design alternatives. Schön (1985) indicates 'talking' and 'drawing' are design languages used by a tutor in design studio, emphasizing the importance of visual and verbal communication in design process. Schön's design studio is traditional and paper-based. With the emergency of Internet technology, virtual design studio has appeared in many architectural schools (Kvan 2001). In virtual design studio different digital design tools serve the two types of the design languages, for example, the software of Whiteboard serves for visual communication, while the chat line software for verbal communication; therefore, paper and digital media have different 'affordances' (Gibson 1979), leading design tools to be adapted in the design process. Kvan (2003) examined the effects of two digital representational forms 'text and diagram' on design process, finding the groups using text only develop more design ideas than those using both diagram and text, and conclude that text can be used by the students as a tool of re-representation and exploration in digital design. Meanwhile Esienman's 'unseen' quoted above raise the potential of digital representation in diagram form.

Do the current digital media interrupt the process of 'problem framing'? To answer this question, this comparative study between paper media and digital media will mainly look at the effect of both media on the design process to investigate the characteristics of 'problem framing'. In this paper we report a pilot study to test the validity of the proposed coding scheme and the initial result of this pilot study.

3. Methodology

Protocol analysis has been extensively used to explore design activities to understand how designers design and also regarded as well suited for a comparative study (Cross 2001). Design is not individual and private, collaborative teamwork is important for both design practice and design education (Kvan 1999). Goldschmidt (1995) carries out a protocol analysis to compare teamwork design with individual design activity and finds the categories of design concern of team members are similar with those of the individual designer. Furthermore team work is of importance in design process in order to address increasing complex design problems that are

hard to solve individually (Goldschmidt 1995). Communication also plays an important role in design studio in form of discussion between tutors and students, or among students themselves (Kvan 2001). Teamwork process-based protocol analysis, therefore, is used in this study to comparing the design activities using paper and digital tools.

3.1 Coding Scheme

In this study we adopt Schön's (1985) description of the design process as framework, using the terms *naming, framing, moving, and reflecting* as our coding schema (Table 1). Furthermore according to Goldschmidt's new design problem (1989), Kvan's new design ideas (1999), and Cross's first principles (1999), we combine *naming* and *framing* into one category. The detail definition of coding scheme and relevant examples are shown in Table 1. Each sentence or utterance was coded according to four variables: *framing, moving, reflecting, and null*. The coding scheme was tested and inter-coder reliability was checked ($r = 0.833$, $\rho = 0.00$), confirming the validity of the coding scheme and process.

Table 1: Coding scheme

Framing	Identify a new design problem Direct from design brief; E.g. *Yeah … we have to provide a sense of arrival at each site access point* Interpret further from design brief; E.g. *I guess the sense of arrival is a kind of signature for the whole area.* Introduce totally new design ideas or realize totally new design information that has not mentioned before. E.g. *Why don't we use the campsite structures?*
Moving	Proposed explanation of problem solving, a tentative solution. It is not a new idea or a piece of new information according to the scheme of 'framing' E.g. *'Maybe some here can put the playground'*.
Reflecting	The situation's 'talk back'; evaluate or judge the explanation E.g. *'Because if we have the large canopy at the top, then we wouldn't be able to see the hospital.' 'Yeah. So you have a quiet place inside. And surround the car park.'*
Null	Not relevant to the above three coding scheme E.g. *'can u see me'*

3.2 Experiments

Three pairs of architectural students respectively engaged in a one-hour design exercise, communicating with each other throughout the whole period. The subjects are at the same levels of education with similar levels of design knowledge and, through academic records, known to be proficient at using both kinds of media. A site design problem is used in this experiment that had been used in a collaborative design research (Kvan 1999); the task is to provide access up a steeply sloping urban park from a bus stop on the lower road to the entrance of hospital on the upper road while allowing a parking area to be accessed from a side road midway up the slope. Subjects were asked to think about design issues of landscape, playground, car park, etc. while accommodating appropriately sloped pathways. The task is an open-ended, 'real-world' wicked problem.

Three different conditions are established to simulate different studio settings (Table 2) using paper or digital tools. In the paper media (PM) session subjects are asked to work collaboratively on a drawing table sitting face-to-face over paper-based design tools. Two digital media1 sessions were established; one (DM1) where subjects are located remote from one another and asked to communicate by chat line while drawing on a shared white board; and a second (DM2) in which collocated subjects are asked to draw on a shared white board while communicating face-to-face.

Table 2: Description on the three experiments

	Paper media (PM)	Digital media 1 (DM1)	Digital media 2 (DM2)
Subjects	2 M Arch students	2 M Arch students	2 M Arch students
Design tools	Paper; pencils; rulers; etc.	Hardware: two computers with keyboard and mouse; Software: Microsoft Netmeeting	Hardware: two computers with keyboard and mouse; Software: Microsoft Netmeeting
Communi-cation mode	Face to Face	Chat line	Face to Face

4. Results

The subjects in session DM2 (face to face) completed the task in 40 minutes; hence we truncated the last 20 minutes in every session, and calculated proportion and frequency of each action (Table 3). We find that in DM1 (chat line), the frequency of total communication is lowest among the three sessions (46), but the proportion of 'framing' is the highest (0.478), confirming the previous findings that users of chat line conditions engaged in the task at hand by focusing on high value communication (Kvan 2002). In DM2 (digital face to face), the proportion of the three actions is more evenly distributed, while in PM session the proportion and frequency of 'reflecting' activities are the highest (percentage: 0.500 and frequency: 150). The data in Table 3 show, however, that the proportion and frequency of the three actions in DM2 and PM are similar. The question remains of whether there is significant difference of those actions during design process among the three sessions. To answer this question, t-test analysis was performed to compare each pairs of the three sessions (Table 4). Figure 1 presents the proportion and frequency of these actions in 5-minute intervals. We find the difference in distribution of 'framing', 'moving', and 'reflecting' appears to be significant difference by comparing DM1 (chat line) to PM (p_f=0.008; p_m=0.034; p_r=0.000) and DM1 (chat line) to DM2 (face to face) (p_f=0.017; p_m=0.016; p_r=0.006), but not DM2 (face to face) to PM (p_f=0.514; p_m=0.213; p_r=0.075). It is also shown *p* values of t-test in the row of 'reflecting' are much lower compared to the other two, suggesting 'reflecting' is more sensitively influenced by the settings of design media.

Table 3: The proportion and frequency of the three actions in first 40 minutes

proportion

	Framing	Moving	Reflecting	Total
DM1	0.478	0.261	0.261	1
DM2	0.340	0.362	0.298	1
PM	0.273	0.227	0.500	1

count

	Framing	Moving	Reflecting	Total
DM1	22	12	12	46
DM2	48	51	42	141
PM	41	34	75	150

Table 4: T-test of 'framing', 'moving', and 'reflecting' in 5-minute intervals

	DM1 vs. DM2	DM1 vs. PM	DM2 vs. PM
Framing	|T| =3.101 p = 0.017	|T| =3.637 p = 0.008	|T| =0.687 p = 0.514
Moving	|T| =3.165 p=0.016	|T| =2.624 p=0.034	|T| =1.369 p=0.213
Reflecting	|T| =3.910 p=0.006	|T| =7.000 p=0.000	|T| =2.087 p=0.075

5. Discussion

This pilot study offers persuasive evidence for the validity of the coding scheme, which constitute the framework of problem framing activities, confirming its feasibility for using in future study. We have hypothesized that different studio settings by adopting different design media might change the ways students engage in 'problem framing' activities. This hypothesis appears to be accepted by comparing DM1 (chat line) to PM, and DM1 (chat line) to DM2 (face to face), while rejected DM2 (face to face) to PM, indicating the setting of DM2 (face to face) does not change the processes of designing comparing to the traditional studio setting (face to face); but the mode of verbal communication might affect the way of students' 'problem framing' activities. In Schön's definition, 'reflecting' refers to the situation 'talking back' to the designers and leads them to reframe design problems, retest them, and re-evaluate them (Schön 1984). The initial results suggest that 'reflecting' is more significant than the other two categories, indicating the effect of the mode of communication on the 'reflecting' activity. Therefore the results here suggest that there may be significant effects in design processes when using digital tools. This pilot tests the methodology; these initial results will be further examined next with a larger sample size.

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Figure 1: Frequency and proportion of 'Framing'; 'Moving'; and 'Reflecting' in first 40th minute