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Omer Akin Carnegie Mellon University

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Case Based Instruction Strategies in Architecture

Ömer Akin, Professor

Department of Architecture

Carnegie Mellon University

Pittsburgh, PA 15213

Abstract

This paper is about Case Based Instruction (CBI) and not about computer implemented Case Based Reasoning systems, as some readers tend to assume.

CBI is a very old method of teaching, particularly in the studio setting. Usually it takes the form of precedent analysis. An empirical study was conducted in order to better understand how experienced designers use cases in the course of a brief design session. Based on this experience a computer based case tool, Electronic Design Assistance Tool (EDAT), was developed and used in studio instruction. Finally, our experience with case based instruction in non-design courses is described.

Keywords

case based instruction, precedent based design, electronic design aids

Normative theories of learning suggest that success is most likely to be achieved when students learn (1) the principles governing events or phenomenon in a discipline, and (2) ways of applying these principles to specific situations to solve problems of various kinds. We call this the *didactic* method. In didactic approach there is a systematic representation of the fundamental principles of knowledge that identify a specific domain upon which a corpus of applications or problem solving skills can be constructed. For example, once students understand the Theory of Thermodynamics, they then are able to apply its principles in different problem contexts demonstrating a command of the knowledge of the sub-discipline of dynamics in Physics. Likewise, Trigonometry or the Pythagorean Theorem explains immutable relationships between geometric elements. These relationships help scientists and designers alike configure complex forms with precision.

When such a theory is altered or replaced by a new theory, the educational approach uses the new in place of the old. First principles occupy the driving seat in fields where such generalizable rules abound. Most academic disciplines, particularly the traditional ones, use a didactic approach.

In fields that deal with professional practice, for example design, instruction appears to deviate from this pattern in significant ways. Students are rarely given robust principles (ones that hold in different contexts), let alone immutable ones, upon which they can construct designs that can be judged infallible, or even reasonably error free. Instead they are given plenty of precedents from which to learn a variety of heuristics. This type of knowledge is fundamentally situated in a context of extradomain information and its pedagogy is *experiential*.

The *experiential* approach to learning is omnipresent, for example, in architectural curricula. Descriptions of design instruction, or for that matter, architectural curricula within which such instruction is found, are invariably of an indirect kind. They describe the stylistic or formal attributes of the architecture that is promoted by the

particular pedagogy in order to explain its characteristics, principles and techniques.^{5,7,8,11,19}

1 Architectural Pedagogy

In one of the most frequently cited schools of education, namely the *Ecole des Beaux Arts* the style of acceptable designs, for example, is based on known and carefully documented examples of early Greek and Roman Architecture. Its pedagogic program is described, often, as a function of principles of design derived from these examples. In the *Ecole* specific principles of composition, media of representation, accompanied with "pattern books" of designs are provided -- for both instructors and students -- in order to facilitate the production of designs of a similar kind or style. Strictly enforced procedures of design are used to supplement the learning experience of the students during the course of their formal training. The pedagogic model is a function of the corpus of designs that the educational system promotes. This connection appears to be inescapable even for other schools of educational thought -- i.e., Renaissance, Bauhaus, Post-Modernism -- or in the case of similar historical accounts by other authors.

The normative model of learning by explicit principles applied to carefully selected instances does not work so well in the context of architectural design instruction. In the case of the *Ecole*, for example, students apprentice under faculty and upperclassmen following closely the examples set by them and the pattern books. The principles of composition that they have been instructed to use are not more immutable than the antique styles from which they have been derived. Their dispensability has surely been demonstrated during the International Style a movement, which simply mustered up the resolve to reject, patterns of the past and replace them with brand new ones. Thus the students of the Modernists were placed in a mode of inventive rather than imitative design. They relied on none of the historical precedents of the *Ecole*, regardless of the type of problem that they tackled

or the client with whom they worked. When the International Style gave rise to Post-Modernism there was a return to the incorporation of historical patterns into architectural styles and then into pedagogy. Subsequently during Deconstructivism, instruction of the students changed once again. This time students were encouraged to work from analytical abstractions of form and composition in violation of both the classicist and modernist principles. Demonstrating once again that the principles of design are at best a relative.

An important distinction of design instruction from instruction in traditional academic disciplines is that students are directed to a corpus of desirable outcomes rather than principles or theories. Based on this, they are expected to produce similar results with novel features. Rarely are they provided with or expected to develop the set of first principles that can guide their own creation of new solution instances. This is principally infeasible because (a) such an endeavor typically takes decades or even entire careers to complete and (b) such principles, if they can be called principles, are much too specialized towards individual designers' needs and objectives. A designer practicing with the Post-Modernist precedents, for instance, may develop a style of historical allusions that are derived from his/her own personal experiences, which can be quite unique.

It is evident then that design instruction represents patterns of learning and teaching that are different from other forms of instruction. Next we will consider some of these differences more specifically.

1.1 Learning through precedents

Knowledge disseminated in the design studio is often packaged in the form of precedents or generalizations drawn from, at best; a limited number of instances -- rather than from first principles. This is evident in virtually all texts, theses, treatises and papers on architectural education, a fair number of which have been sampled here. ^{6,7,8,9,11,18,19,20}

Precedents in this sense are specific designs or buildings, which are exemplary in some sense so that what architects and students glean from these examples, can support their own designs. These precedents are very often past solutions to specific design problems. Normally, they are used to highlight a handful of design issues: such as, elevation design, systems integration ideas, structural concepts, plan circulation diagrams, section-volume concepts, and so on. In some cases precedents are negative ones, illustrating some sort of a failure and instructing students on what not to do.²

Learning, in these instances, takes place through examination, analysis and abstraction of the information contained in the case representation by the students, occasionally with the help of the instructor. The format of this analysis is generally well defined at the onset. Students are asked to research a building, collect relevant information, usually along some specific dimensions (like the ones cited above) and present it formally to peers in the studio or the office. In subsequent phases, the role of the case in generating designs is rather irregular. Dictated by circumstances of board crits or other reviews of the work, which is referred to as a "situational" mode by others, 6 some design rules are abstracted from the cases. These are extremely useful in evaluating design ideas or generating new ones. Yet the fact remains that the most productive use of case analysis in design is conducted in an informal and *ad hoc* fashion.

1.2 Conceptual versus physical knowledge

Nevertheless the abstractions derived from the cases are invaluable in bridging between the "conceptual" and the "physical" variables that are the basis of spatial design. 9 Conceptual variables are the schemata that provide the underlying order and structure for an aspect of an architectural design. To provide the various functional and aesthetic values which are the hallmarks of all "good" designs, the physical elements of the building design must be integrated with one another based

on globally constraining variables (loosely called "concepts" or "design concepts"), dealing broadly with such criteria as structural integrity, clarity of circulation, appropriateness of proportions, and so on,. Most successful designs at least ones that are recognized in the field as notable have explicable ideas underlying these dimensions: for instance, the core and open plan layout of the Farnsworth house by Mies van der Rohe, the served and servant spaces of the Salk Institute by Louis Kahn, the exploded box of Fallingwater by Frank Lloyd Wright. How these *abstract* concepts in fact give rise to and later are used to justify and explain explicit physical descriptions of designs is a particular skill that the architectural student must learn in school.

This requires that the knowledge of physical elements as well as that of conceptual constructs is readily available to the student. The student must be skilled at using these as the foundation of the design ideas generated and ultimately the drawings that are produced. At Fallingwater, the location of the windows at the corners and the horizontal banding of the elevations by means of inverted beams of the structural system, for example illustrate how the physical elements reinforce the architectural concept and vice versa.

1.3 A hands on learning experience

A significant feature of the mechanics of instruction in the design studio is the constant interplay of skill and knowledge or theory and practice. While there may be little in the way of first principles of design, there is a great deal in the way of discovering how principles affect the solution to a specific problem and how specific solutions may illustrate larger principles. Furthermore, this is done in a generate-and-test mode. Students learn by applying principles to designs and inferring principles from designs. Faculty play the role of coach or critic in the course of this. Cognitive skills supporting this operation develop after many trials and almost just as many errors.

Knowledge and skill are interconnected through experience in studio work. Students are expected to actively use, for example, solar factors, thermal conductance relationship, and structural ideas in creating new building enclosure details. In this process, one factor informs the other. Students learn not only about the concepts that work but how to put these concepts to work, situationally.

1.4 Simulation of design in the outside world

The early precedents of the studio were actual professional offices. Students were apprentices learning from more experienced students and the master designer who ran both the office (or the atelier) and the classroom (or the studio). As educational systems became more formalized, this aspect of architectural education became a limited version of the original set up. Students continued to learn in the context of design projects issued by the instructor and undertaken by peers in the studio; but this time the entire arrangement was artificial. The project was hypothetical. There was no real client. No monies exchanged hands or professional responsibilities discharged. Students pretended to do a realistic project and the faculty behave as if they may be clients and design critics at once.

Thus the goal of the present studio setting is to simulate, albeit in a very limited sense, the reality of the architectural design office. This is particularly difficult because the precedents that are available to the student in the classroom are usually devoid of the complexities and realities of the world of architectural practice. Clients, officials, financiers, and a host of consultants that normally define the parameters of a design are not present. Furthermore, the instructor who is the only conduit to the world of practice is often removed from practice due to academic responsibilities.⁵

Nevertheless, the studio setting creates an environment within which students have to learn to think on their feet and respond intelligently to unexpected demands and uncertain design requirements. In spite of the best efforts of instructors who sometimes try to create a manageable world of design possibilities, other,

imaginative design critics insist on admitting virtually any design issue, however irrelevant, into the criticism of a student project. This requires that student's address, during a review session, design issues that they were not prepared to address. As difficult as this test may be, the educational value of the experience for the student is invaluable. So long as students can escape some of the detrimental aspects of such experiences, they have a lot to gain from it. After all, this is not very different from what happens in the professional world of practice.⁶

1.5 Weaknesses in design instruction

There are three kinds of weaknesses in design instruction of the kind described above: motivational difficulties, insufficient instruction of the design process, and inefficiencies in learning.

In the case of "trial by fire" type of instruction, unrestricted criticism directed at students' work can become distracting and counter productive not to mention demoralizing and destructive. Students can pick up on the cynical aspect of such a relationship with faculty and may become disheartened about their own progress, even the particular career choice they may have made. When this approach works, it is done in a premeditated manner rather than in an *ad hoc* manner. Criticism is carefully delivered; and perhaps most importantly, students are coached about the rationale of the method and its benefits, beforehand.

Owing to its traditional focus on the product-based precedent in the design studio, students are often provided with little or no instruction on the process of design. When students analyze a precedent they start by understanding its physical characteristics and from there they move onto abstracting the conceptual aspects of the design. Nowhere in this picture is there any room for the analysis of process. Unless for some unusual reason the process is manifested in the overt physical characteristics of the final design, such as, building failure cases, students are

generally uninformed about the process of design. Thus the present form of design instruction does not support the teaching of process or design methods well enough. In the situational model of instruction, where the relevance of general design principles, or specific design solutions, for that matter, hinge upon circumstance and chance, students are generally on their own to devise the means to get to the desirable end. Their search resembles groping for a needle in a haystack, since they do neither have sufficient experience to structure their solution domain (i.e., the haystack) nor sufficient command of their process to adapt it to the problem domain (i.e., the groping). Analysis of precedents is utilized in structuring their design approaches. Derivation of principles of design occurs as a result of to happenstance or the personal interests of the instructor. When there is generalization from examples, improvisation and inducing form very small lead to a good deal of design inefficiency and confusion about instances and principles.

2 The Case Method

Overall purposes of teaching include a large variety of cognitive activities including thinking, sensing and perceiving, learning of facts and theories, reflecting, skill acquisition, applying rules and principles, solving problems, and so on. While there is a dose of each of these in any form of teaching, in professional education programs the principal focus of the effort is expended towards how to solve problems. This involves the hands on acquisition of problem solving skills and the body of knowledge that can support the application of these skills to a wide selection of problems. We saw in the earlier section how instruction methods geared towards this sort of educational experiences can be both liberating and limiting in certain ways.

The inclusion of such approaches in the educational environment of the university invariably proves to be beneficial to the intellectual climate of all parties concerned. The general objectives of learning in the university setting actually provide many persuasive arguments for the validity of "learning activity in the presence of

knowledge"²² (pp. 218-219). This means that didactic forms of instruction invariably benefit from the inclusion of applications along side of formal knowledge. This point of view, of course, is particularly cogent for professional education. In fact, for professional education to succeed the core of the educational experience must consist of the representation of applications and actions in the profession. Thus, it is worthwhile to consider a broader sampling of these approaches to professional education.

A particular method developed at the Harvard Business School during the late 60s and early 70s provides a well-structured approach to the area of professional education: the "case method". In this approach, a problem-action context is established through *cases* within which knowledge and skill acquisition takes place. Students not only learn about the underlying principles but also the processes, which are related to these principles.

The essence of the case method is presenting problems through past cases and the context of these cases documented in written form. The learning process centers on the discussion of cases in the classroom. It is paramount that students study the cases before hand and engage in debating the crucial aspects of each case in the classroom. In this way students learn about the principles of the domain through the cases or about knowledge through action. Schön, ¹⁸ an early student of the method and an influential educator in the field of architecture has aptly coined the term "reflection in action" to describe the process that takes place in the design studio which is akin in may respects to the case method.

Key roles that the instructor plays in this method are facilitating the discussion around a given case, selecting and presenting the case, and in some instances codifying and structuring the case. All of these are complex and poorly understood processes. The contributions of the work done at the Harvard Business School are most notable in structuring these activities and training instructors in the case method.

The successful discussion of cases involves several important goals. First and foremost the discussion section must function as a learning group. Next, there has to be high levels of student involvement. Finally, the instructor must play a role of facilitation and direction of the discussion without dominating it. This is achieved through a proper training of instructors and discussion leaders in the case method. This instruction is also structured as case based instruction (aptly so) illustrating the principles of leading successful discussions through case examples collected in the classroom.⁴

The other key ingredient of the method, obviously, is the cases. Historically, cases used to consist of brief, at times, cryptic descriptions of situations, which then had to be elaborated extensively on subsequent stages of the instruction process. Currently, however, cases have justifiably become elaborate descriptions containing three indispensable aspects: (1) a description of the context that surround each case, (2) description(s) of the various stages of progression the case has gone through prior to its resolution as well as the solution, and (3) a description of the processes or methods that are relevant for these states. It is important to underscore the significance of the latter -- particularly for instruction in architecture -- where the cases used traditionally consist of only context and state descriptions, by and large, ignoring the process aspect.

The corpus of cases and their proper representation is obviously the prerequisite for any successful implementation of this method, regardless of the discipline of application. One of the very important services provided by the Harvard group is the documenting and making available to other institutions of a rich corpus of cases from which to teach business administration, in the classroom.⁴

3 Concepts of Case in Architecture

Now that we have considered architectural education in the general and case based instruction as a sympathetic pedagogic approach, let us introduce some terms that are critical for understanding case-based architectural education.

Lets start with the central concern of the field. An architectural problem constitutes a set of those that address the fulfillment of human purposes related to human occupancy, such as visual appeal, mechanical enclosure, or structural integrity.

There have been many attempts at succinctly capturing these purposes starting with the earliest know treatise on architecture by Vitruvius.²¹ This is an impossible task for obvious reasons and we are not attempting to undertake it. Rather we want to start with a tautology upon which to construct other more useful concepts.

What then is an *architectural product*? We know these products as buildings, landscapes, bridges and the like. The contemporary architect however produces designs for physical objects not the objects themselves. In this light an architectural product is the description of a potential solution to a given architectural of problem. How is the *architectural process* related to the product? Similarly, the architectural process is merely a description of a procedure useful in solving a given problem. We have seen in the above discussion that both the process and the products of architecture have something to do with *precedents*. A precedent is previously developed product or process, which can be used to model new solutions in the problem domain of architecture. This is our lead into the discussion of cases. An *architectural case* is the codification of all of the information necessary to describe a precedent, which can be used in solving new architectural problems. A *case base*, then, is the collection of instances or *cases* usually codified in a manual or computational database.

Finally, *case based instruction* is the dissemination and acquisition of requisite knowledge in a domain principally through the systematic examination of cases encoded in a case base.

4 Case Based Reasoning

Before we move onto Case Based Instruction (CBI) it is worth noting that the area of case based applications, in general, has benefited greatly from research in the area of Case Based Reasoning (CBR). CBR as a method in AI is considered to be the brainchild of Janet Kolodner. 12 Her work developed a computer-based system that could browse a repository of cases (recipes), find a match to the problem at hand (preparing a dinner) and adapt the recipe to the problem at hand (prepare a vegan dinner out of vegetarian recipes). The technique proved to be not only a powerful generative system but also one that would find broad applicability in other areas. For example, Mary Lou Maher¹³ in building an expert system for the engineering design of high-rise structures used a case base to initiate conceptual design ideas. Even more relevant to our topic here, Rivka Oxman¹⁵ developed a case base that assists designers in consulting design precedents. Her contribution is particularly salient since she used cognitively based stories, which consist of design issues, concepts and form, as the indexing schema to underpin the browsing and matching mechanism of the system. Kolodner and associates 12 also emphasized the importance of this method in the area of building design through their work on ARCHIE, a case based architectural design system.

As we indicated at the outset, while this literature is important, and there is a lot more of it than what's cited here, ¹⁶ an extensive review of it is neither practical nor relevant to the current topic, which is case based instruction (CBI) in architecture.

5 Case Based Instruction in Architecture

Our work in this area can be described as a three-prong approach. First, we developed a manual approach to presenting non-studio material using a case based technology. This is aided by online and interactive case libraries and course materials, which can be found at http://caae.phil.cmu.edu/edm/architecture, and http://caae.phil.cmu.edu/edm/architecture, and http://courseinfo.web.cmu.edu, respectively. Second, we empirically studied case use in architectural design. We collected data from designers regarding their use of cases. The results of this study while not conclusive have been instrumental in developing the next stage of our work. Finally, we developed a case-based tool called EDAT (electronic design assistance toot) to assist with hands on instruction in the studio. We will describe all three efforts in the following sections of this paper.

5.1 Case based instruction in non-studio courses

Case based instruction in non-studio courses has a special place in the context of architecture education. Four forms of instruction, didactic, rhetorical, synthetic and experiential have an important place in the context of a full architectural education program. Lecture courses generally rely on the didactic method. Historical periods of style, for example, Mannerism, Post Modernism, Modernism, are defined and illustrated with examples. Students are told what each of these is and are expected to remember what they are told and how they should use this information, in the future.

Seminar classes use the *rhetorical* method more prominently. They rely on the understanding of sample texts and images from a relevant domain in the context of debate and discussion. Larger principles are derived from these discussions in an inductive fashion, as opposed to the deductive style of lecture courses. Studio instruction focuses on the repeated practice of *synthetic* skills interspersed with criticism (or *rhetoric*). The primary skill to be developed is, however, generative or synthetic.

Experiential instruction situates the knowledge to be gained into a simulated context provided by a case study. This complements the deductive or rhetorical forms of instruction used in architecture education. It balances the abstractness of the other forms and dovetails with the "case generation" activities prominently featured in the design synthesis studio (Figure 1).

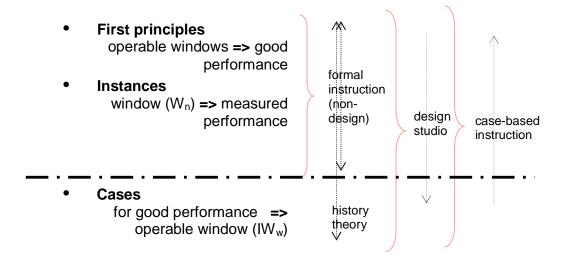


Figure 1: Summary of instructional methods in architectural curricula

Cases create a fertile ground for exploration of interesting subject matter and unique learning experiences. Students tend to follow the material with greater interest. Their cognitive faculties are not unduly taxed as they learn abstract material. A relevant case study is always handy to connect abstract concepts to concrete examples. Furthermore, case studies lead to engaging exchanges between students, between faculty and students, between students and the case material. This exchange invariably leads to discoveries of new relationships and conclusions some of which have general implications reaching beyond the case from which they are abstracted. Also, the number of cases that illustrate any given subject area seem to be surprisingly large. Our application of this method in the classroom started in 1990 in a course dealing with issues of decision-making in architectural design and then included issues of ethical decision-making in design. In both instances, case studies have abounded. Virtually any building design process if documented has important

lessons for decision-making and ethics. They also illustrate important theories and techniques such as Utility-Value Theory, Risk Analysis, Naturalistic Decision Making, Rational Ethics, Institutional Ethics, and Rights/Consequences/Virtues based ethics. There appear to be as many potentially relevant case studies as there are architect-designed buildings.

To date we have developed dozens of cases. The ones that are permanently used in the presentation of the course include the Sydney Opera House, Pruitt-Igoe public housing complex in Saint Louis, University Center complex at Carnegie Mellon in Pittsburgh, Hancock tower in Boston, Kansas City Hyatt Regency, Citicorp Tower in New York, Crystal Palace in London and Fallingwater in Bear Run, Pennsylvania. Our decade long experience with case based instruction leaves us with a distinctly positive impression of students' learning and course satisfaction indicators related to the overall approach. This result has been born out by students evaluations conducted time after time in the course cited above. Yet, these findings are anecdotal and informal, at best. We also wanted to conduct better structured experiments and projects that verify the value of case based instruction. The following discussions deal with such efforts.

5.2 Exploring Cognition of Cases in Architectural Design

The premise of our empirical study has been one and the same with that of the entire paper: designers use cases while developing design proposals. Therefore, we set out to examine the design process through empirical methods in order to verify the use of architectural cases.

The empirical method we chose to use is *protocol analysis*. This permitted us to collect evidence that is comprehensive and diverse enough to study a variety of relationships and hypotheses, even ones that we did not consider at the outset. In other words, we employed a deliberate research strategy of casting a wide net,

expecting to be inclusive of the broadest set of issues related to the phenomenon in question.

The task was a building design problem using a realistic program and a casebook containing specific examples of a building type relevant to the design problem. The design problem chosen was the National Jazz Hall of Fame and Museum. The architectural program was roughly 70,000 sq.ft. of interior and 30,000 sq.ft. of exterior space located in the cultural section of the Oakland district of Pittsburgh, Pennsylvania.

Three subjects, all practicing architects and adjunct faculty at Department of Architecture, Carnegie Mellon University, participated in the experiment. They were asked to develop a proposal for the client, who was portrayed as the principal donor to the project and a person who is impressed by the exemplars contained in the casebook. The casebook consisted of text, diagrams and photos of five museums: Suntory Museum in Japan, Carnegie Science Center in Pittsburgh, Centre Georges Pompidou in Paris, Holocaust Museum at Washington, DC, and the Rock and Roll Hall of Fame and Museum in Cleveland.

Each design session of the subjects were audio taped and all writings, drawings, and sketches produced during the design sessions were documented. On the average the subjects spent 1.5 hours per session. While the overall performance of the subjects bore clear evidence of years of professional experience, there was considerable divergence in the proposals developed and only one subject developed a substantially graphic proposal.

Protocols S-1 and S-3 bear out our assumptions about the "wide net" approach of protocol analysis studies. However, they are of marginal utility to us here. Subject-1 did not go too far beyond the problem understanding stage. He generated only simple functional diagrams of his design. Since the casebook contained information that went well beyond these issues, we did not include this subject's protocol in our detailed analysis. Similarly, Subject-3's protocol was excluded from the final

analysis. He concerned himself exclusively with the financial aspects of the problem. Early on, he concluded that the budget for the project was inadequate and that he would not make any concrete proposals for a problem like this. Since this could not happen during the brief protocol session, Subject-3 did not develop any proposals. Subject-2, on the other hand, developed a detailed preliminary proposal represented by an axonometric view, a longitudinal section, a transverse section/elevation and a number of exploratory sketches. This protocol yielded concrete evidence about case use in design. First we looked for evidence of references to specific architectural cases. The summary of these findings is included in Table 1. On the far right column we show a number of such references. In searching for these we discovered that Subject-2 also made references to other non-architectural constructs, principally nouns, which functioned like architectural cases. These generally fell under the category of *metaphors* some setting up parallels between the design and generic (or prototypical) entities, such as "the rhythm in Jazz music," while others to specific (or exemplary) entities, such as Dave Brubeck's "Take Five" (column 6 of Table 1). Table 1 also specifies the paraphrasing of corresponding utterances (column 5), the number of times references are made (column 4) and the design issues and subissues (columns 2, 3) being tackled through the metaphors or cases referenced. Based on this analysis there are several important observations we can make regarding the use of cases.

Table 1: Analysis of Subject-2's Protocol

EDAT topic	Topic	Sub-topic	Freq. (n)	Utterance	Metaphor: exemplar/ prototype	Case
11 504	circulation circulation	— entrance	<u> </u>	queuing is a nightmare; circulation	music / wedge	
				is like sound traveling inside a horn	entrance	Cobb - negative)

-		circulation	sequence	3	program elements; dilemma - starting at the core and moving out; arrival - ending at the same point (duality);	spiral; 3-d spiral; wall as circulation spine; interlock; float	
4	197	composition			_		
5	563	composition	geometry	2	curve and entry are throwing people onto their path: theater as the reconciliation between circle and the square		
5	502	composition	grid	1	random column grid		
4	199	composition	hierarchy	1	piloti here with x bracing	piloti to hold up the hall of fame	
5	570	composition	massing	2	origin and destination stacked on top of each other: mass to the back of the site and open towards 5th Avenue		Soldiers and Sailors Memorial (Hornbostel)
•	10	composition	metaphor	1	tie the shell to a jazz instrument or clef	instrument, base clef	
4	198	composition	plan parti	4	probably a very good parti for the Rock & Roll Hall of fame = flexible: spiral shape is only circulation not a form maker; spiral is the only sacred element here	context is the form giver and all adjoining buildings are rectilinear	Centre Georges Pompidou (Piano and Rogers - from case book); Sainsbury: Pittsburgh Ath. Assoc., Soldiers and Sailors Memorial (Hornbostel)
5	594	composition	point / counterpoint	1	circle and square = container and circulation		
-		composition	public / private	2	control inside the spiral; outside of the spiral informal, public: retail on outside of spiral wall		
8	313	composition	repetitive / unique	1	Hall of Fame roof is unique element	bull horn	
5	563	composition	rhythm	1	repeated elements of the entry sequence along the curved wall		
5	506	composition	space definition	1	insulation of displays in the lower level		Rock & Roll Hall of Fame (Pei, Cobb - from case book)
:	23	construction	_		_	_	_

	construction	walls	2	spiral as double wall to solve duality of entry and circulation; circular wall as a chronology of major jazz events	"jazz wall of fame"	Mia Lin's work
744	experience			_		
744	experience	overall	3	interactive, monumental, attractive, memorable, flexible, diverse: path through history, could be a formal driver: sanitized version of Rock and Roll; Jazz is out of the basement, not pretty	improvisational space: nautilus shell; Fibernacci	Cobb): Vietnam War Memorial,
946	program					
505	program	functions	6	hall of fame is becoming the heart of this building; sequence like R&R Hall of Fame	sacred space; heart / sequential	Rock & Roll Hal of Fame (Pei Cobb) - but different experience
7	represent'n					
30	represent'n	elevations	3	rectilinear elevations on all three sides; respectful of Bigelow elevations; active side to West; floating roof	floating element of roof; animated -pixels of images	Pittsburgh Athlet Association, Soldiers and Sailors; Mies roof form
28	represent'n	plans	5	concept: spiral, [functions], straight shot out for retail; flip plan over its own axis	if it does not work try the opposite	
29	represent'n	sections	2	not studied on site yet; ramps at various elevations, cover with single roof		National Gallery Berlin (Mies Var der Rohe)
	represent'n	site	3	I'm gon'na draw the site in no particular scale; trees on Bigelow side	1"=32' scale should be required	
16	site			_		
251	site	context	2	all buildings around are rectilinear – so make rectilinear facades, not circular		Pittsburgh Athle Association, Soldier's and Sailor's Memoria
20	systems			_		
910	systems	enclosure	1	not studied yet		
911	systems	roof	1	a flat structure with a random column grid		

Guggenheim (F. L. Wright) effect

5.3 Discussion of protocol analysis study

First, in developing conceptual designs represented graphically cases with visual/graphic content are commonly used. Out of 55 episodes during which different design issues were visited 31 contained references to cases. There were a total of 25 references to cases. Some cases were referenced multiple number of times. The total pool of distinct cases used in these references were 14, referring to 11 issues/sub-issues in all. These were the Holocaust Museum by Pei & Cobb; the Vietnam War Memorial, Civil Rights Memorial, and Memorial for Women at Yale by Mia Lin; a prototypical museum by Le Corbusier; the Rock & Roll Hall of Fame by Pei, Cobb; Centre Georges Pompidou by Piano and Rogers; Sainsbury by Grimshaw; National Gallery in Berlin by Mies Van der Rohe; the Guggenheim by F. L. Wright; the Soldiers and Sailors Memorial by Hornbostel; Village Vanguard at New York and the Pittsburgh Athletic Association in Pittsburgh.

These cases were used in a variety of ways in developing design proposal. Some were used to propose a building massing that was consistent with the physical site context, particularly with respect to the two adjacent buildings: the Soldier's and Sailor's Memorial and the Pittsburgh Athletic Association. Some were used to generate ideas as well as evaluate those that were generated, such as circulation, building experience, structure, and circulation. Often the cases were recalled in conjunction with a specific design issue as shown in Table 1. Others were either reused in relation to related issues, such as the functional aspects of the Rock and Roll Hall of Fame, or were simply re-recalled in connection with these. While these distinctions may be important for case based systems design, the cognitive processes responsible for them can be described only with more detailed analysis than the one we provide here.

Two important distinctions in case use that we observe at the present granularity of analysis however are that: (1) cases are used on the basis of singular aspects at a time, i.e., they need not be made available to users, lock stock and barrel; and (2) they are used for generation or for evaluation purposes, i.e., the kind of information recorded for evaluation (criteria of design) are potentially different from the kind of information needed for generation of designs (design constraints).

A finding that we owe to the "wide net" strategy adopted in this research project is the use of metaphors during the conceptual phases of the design process. There were 25 distinctive metaphors used during the protocol. These were distributed among 37 occurrences in the protocol corresponding to 12 design issues, in all. At this time we do not know the generative and evaluative importance of metaphors but their use in design appears to be similar to cases. They characterize specific abstractions of the design being generated as described in the issues/sub-issues column of Table 1. It certainly appears that this is another area worthy of investigation.

6 Computational case based instruction in the studio

To effectively harness a case based instruction (CBI) approach to design it must be formally represented. A formal representation would lead to a robust manual method or even computer based ones.

There are, however, several difficulties with such an approach. First, with most building types, there is a very large set of instances that illustrate them. Second, even if one were able to include a plethora of examples in a case base, not all of these would be relevant for a specific design problem. In a museum design project, for example, one may be interested in responding to a variety of issues. These include the use of modern materials, new construction techniques, advances in art preservation, and changing museum visitation patterns, most of which would be absent from many historic examples of museum design. Furthermore, other building types (of the non-museum variety) may have features that are relevant, such as

buildings in a similar climate, buildings surrounding the site, and buildings appealing to the owners.

Thus, in order to use a precedent in design, first it must be identified as relevant. This is generally identified as the matching problem. There are several different strategies of matching a precedent to a problem at hand:

- Solution matching: the prototype provides a solution, which can with little modification be used to satisfy the current design problem.
- Sub-solution matching: the prototype contains sub-solutions, which can be synthesized into a solution in order to satisfy the current design problem.
- Search space matching: the prototype represents a domain of search, which
 can be used to limit the scope of investigation relevant to the current design
 problem.
- Process matching: the prototype illustrates an approach or method that can be applied to solving the current design problem.

Using one or more of these strategies, the designer can meet basic performance criteria within a reasonable amount of time. This approach is not without its critics. Some, for example, fear the potentially limiting effect of precedent-based design on creative and inventive solutions. However, there is no concrete evidence that supports the validity of such a concern. If anything, there is ample evidence documenting that designers actively and frequently use precedent based processes.^{1, 10,14}

Therefore, documentation of cases in a computer has to respond to a variety of user perspectives. Many building types, many instances in each type, and many different attributes of these types and instances should be represented. The interconnections between cases and store/access operations that need to be carried out for each case must also be supported. Once a match is found there is the further problem of adapting the matching case to the problem at hand. Assuming that one can develop

a CBI system that performs these tasks, there is the separate question of how to support learning in design through CBI. Our intent is to shed light on design education through the exploration of the potential role of CBI systems and tools.

6.1 Cataloging standards of practice

One of the important uses of a CBI is to encode landmark designs in a given field. This can support the conventional form of precedent-based design using exemplary designs. There is also great value in building case bases around the work of individuals and groups in an office setting. For example, if a firm is specialized in designing health care facilities, employees learn cumulatively about the dos and don'ts of health care design, and 'good' and 'bad' solutions to health care design problems. These design practices are more often than not reflected in a particular design solution rather than in general principles. Saving and reusing a historic array of design cases in an office can be of immense value towards establishing internal standards of design practice. In this way, solutions developed at one time or by one individual in the office can be easily disseminated to others. This can work just as effectively in the studio setting. A case base used to save cases from a cross section of studios or in a given studio over time can become a powerful pedagogic instrument.

6.2 Design presentation

Another important aspect of case based precedent documentation is its potential value in promoting presentation of designs in the computational medium. Computer Aided Architectural Design (CAAD) applications, having been introduced into the traditional design environment of drafting boards, parallel rules, and tack boards, appear to emulate these manual forms. Drafting systems emulate parallel bar operations and entering of data line by line. Drawing representations primarily use the paper-pencil metaphor. Presentation still relies heavily on hard copy output.

There are many practical reasons that justify these approaches, yet they prevent the

new medium from developing into its own and reaching its ultimate potential. We envision that the basic CBI functionalities of saving and browsing cases are akin to asking for and obtaining information or explanations about a design. Thus, we see a potential use for a CBI, which so far has not been exploited by existing case based system: presenting of new design work to clients, reviewers and teachers. We believe a well-documented case, stored within a case tool can support a range of useful design tasks, such as, generating, evaluating, and reporting on design proposals. This can lead to productive interactions between design instructors and students. We expect that EDAT will support this functionality.

6.3 EDAT: A tool for practicing case based instruction

The goals that initiated EDAT's development are:

- A centralized store for research documentation gathered by students in the early stages of design. This student documentation would tend to relate to design issues and building types being addressed in that year's studio.
- A tool to perform performance analyses of this gathered design data, using
 third party applications. This would require that students gather particular
 data in a pre-specified format. This aspect of EDAT's functionality has not yet
 been implemented.
- A presentation tool for students' electronically produced design documents.
 The browsing process in which students engage to find particular information about buildings could be adapted to the presenting of student's design work.
 Students would have the responsibility to organize the structure of their designs within the case base such that important aspects of their designs are legible and easily accessible using a browsing process.

6.4 Data access and storage in EDAT

In EDAT, data is stored in a relational database. The implementation environment used was the relational data base tool by Microsoft called ACCESS. A complete description of software development issues in EDAT was published earlier.³

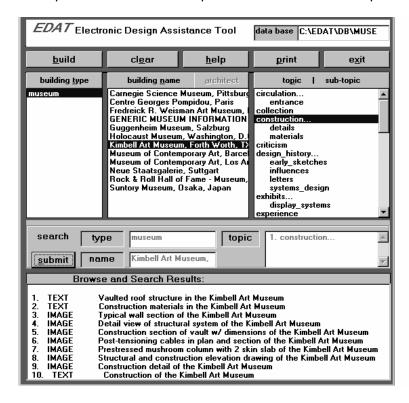


Figure 2: The browser interface window of EDAT implemented in Visual Basic

An important part of the case-building process within EDAT is the design of a topic
tree for each building type. Different building types may share various topics, but the
assignment of each topic to each building type is at present a manual process. There
is no prescribed structure intended for these topics and the virtual topic-trees that
contain them in their nodes. This is one of the greatest strength of EDAT: its basic
identifiers or indexing of subject matter are completely user defined. It does not
assume that information must be organized in any particular way. However this
places on the case-builder the burden of creating a coherent topic tree. Since the
manner in which facts are indexed has a great effect on how these same facts are
retrieved from the case base, the conceptual process of designing a topic tree for

each building type lies at the heart of both information retrieval and information storage in EDAT.

The primary interaction that users have with EDAT is through the main case-browsing window (Figure 2). This window provides for the processing of queries to the database as finding and displaying information stored in EDAT. This consists of:

(1) a menu bar with 'Help,' 'Clear,' 'Print,' 'Exit' and 'Build' (or "connect" to database) buttons; (2) browse windows with building type, building name, architect, and building topics/sub-topic filters; (3) a submit panel showing all user selected fields from the browse windows (4) a submit button used to query the database based on all selected fields as shown in the search windows, and (5) a browse and search window displaying the facts retrieved from the query processor.

Browsing the database in EDAT is accomplished through several filters. The filter criteria are building type, building name, architect, and topic. The criteria can be applied in any order and any or all can be omitted. As one clicks on the buttons of Building Type, Building Name, Architect or Topic/Sub-topic, the case base is queried for these items. For example when one clicks on the Building Name, all building names are returned which also satisfy all previous selections. If no other items had been selected then all building names in the case base are displayed. Browsing is therefore an additive process of constructing more and more restrictive constraint sets. The more restrictive the filter set becomes the fewer the number of facts returned from the case base.

Selection of the 'Build' button on the menu bar brings up a Microsoft Access interface with the EDAT database loaded as the current project. This interface provides access to a series of screens (Figure 3) allowing the user to add to or modify the database. Modification of the database refers to the addition or deletion of topic nodes from the database structure.

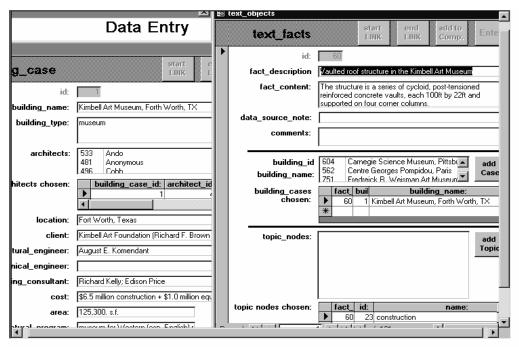


Figure 3: The primary interface window of EDAT implemented in ACCESS

To add data to existing topic nodes in the database, the user must identify the data type (raster image, text file, AutoCad file, etc.) and provide a full path to the current location of the file to allow later retrieval of the file from the database. The screens for the addition of data to the database allow the user to input information into both base and relationship tables from a single form.

User's selection of specific facts from the listing in the browse and search results window automatically launches the fact windows. Each database fact is launched in a separate window for viewing. Fact windows may contain short text facts, text files, raster images or AutoCad drawings. Raster images are displayed as bitmap images. AutoCad files are treated as embedded objects using OLE (Object Linking and Embedding). The selection of an AutoCad file from the search results window launches a fully working AutoCad user interface with a copy of the selected AutoCad file as the currently active file. The user may manipulate this file as desired within the AutoCad window and save the file to another directory without altering the original drawing in the database.

6.5 Deployment

We deployed EDAT in an undergraduate design studio within the Department of Architecture, Carnegie Mellon University. The studio contains eleven PC's. Each PC has a 120 MHz Pentium processor, 24 Mb of RAM, a 500Mb hard drive, and Windows NT 4.0 as the operating system. The machines are networked to a common server. Existing EDAT data including 13 museums and generic information on museum design resides on the server. Each student is assigned a machine containing a copy of the executable EDAT code.

Based on our current experiences with EDAT, we have learned some valuable lessons. On the positive side we found that:

- 1. An electronically maintained case base of architectural exemplars, such as EDAT, has greater depth of information on a broader set of examples than what is normally achieved in a traditional studio context through precedent analysis studies. Each year's work adds to the case base a new set of entries. New information gathered on earlier entries are added to the case base making each entry progressively more comprehensive and accurate.
- 2. A computer based case base has obvious advantages in a studio taught through computers. Information can be readily moved to the CAAD medium from the case base and vice versa. As more and more design studios use CAAD, we expect the value of tools like EDAT will be recognized more broadly.
- 3. The repository of information contained in EDAT does not have to be limited to those found in printed literature. Analytical tools based on computer technology can be used to generate new data and to conduct on line analysis. In this way important performance indicators, such as thermal acoustic, lighting, can become part of the case analysis.

On the negative side, we learned that:

- Building a case base with any amount of information that would be sufficient to interest the user is extremely time consuming.
- When data is entered by a group of students assigned to the task, it is difficult to maintain quality standards pertaining to both content and format.
- Line any other computer-based application dealing with large quantities of information EDAT presented difficult problems of real estate management problems on the computer screen and image quality.
- 4. Finally, and most importantly, it became evident after using EDAT in the studio that out intuitions about the use of cases in the design setting are not entirely accurate. In fact, it is fair to say that we do not understand the phenomenon of case based instruction adequately.

7 Conclusions

One of the first things we realized in comparing the findings of the protocol analysis study with the experience of EDAT was that the issues and sub-issues raised in the protocol analysis study very closely resembled the topics and sub-topics that were used in the EDAT database (see next section). Only 12% of the issues did not correspond to a topic. This suggests that the topics created in EDAT by students are by and large representative of the scope of issues covered, independently, in the design session.

The most interesting aspects of our findings, however, have to do with some of the commonly held beliefs about how designers use cases in design. We were both surprised and pleased to find that some of these intuitive notions were not supported by the data.

In spite of the great diversity of purposes and forms of case usage described in the earlier sections, our most basic finding was the ascertaining of the use of cases

during design. Strangely, this was a pleasant surprise, as like most researchers, at the outset, we had a basic skepticism about our central premise.

Another one of our original beliefs that was fully supported was the fact that EDAT produced a far better organized and accessible case base compared to those prepared earlier in the same studio context. Student's work had to be supplemented by that of a "librarian" who was charged with editing and formatting the data to achieve greater consistency. While this was a non-trivial task, the result was well worth the effort.

On the other hand, we found out that cases are not full and complete descriptions of earlier designs. In fact designers retrieve earlier cases for considering relatively narrow design features rather than wholesale information. Furthermore, cases are used more often as evidence to corroborate designs already generated. They supply the criteria for evaluating them. The active use of a case to generate complete and complex solutions is not supported by our data. This is clearly inconsistent with case based reasoning strategies that assume that designers do similar tasks manually or have the desire to do so.

Finally, we came to the humbling realization that our understanding of case use in design is deficient. Whether this use results in superior designs or how it compares against other methods of design appear as interesting questions to be pursued in the future.

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