Building A Computer Aid for
Teaching Architectural Design Concepts

by

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Abstract

Building an aid for teaching architectural design concepts is the process of elaborating topics, defining problems and suggesting to the students strategies for solving those problems. I believe students in Environment and Behavior (E&B) courses at Georgia Tech can benefit greatly from a computer based educational tool designed to provide them with experiences they currently do not possess. In particular, little time in the course (outside lectures) is devoted to applying concepts taught in the course to the studio projects. The tool I am proposing provides students with an opportunity to critique architectural environments (both simple examples and previous projects) using a single concept, "affordances". This paper describes my current progress toward realizing the goal of designing a tool that will help the students to understand particular concepts and to integrate them into their designs. It is my claim that an integrative and interactive approach - creating a learning environment and making both the students and the environment mutually supportive- is fundamentally more powerful than traditional educational methods.

INTRODUCTION

Architectural education requires that students understand concepts from a variety of domains and utilize them in design. However, students sometimes do not learn these concepts in a way that allows them to transfer and apply those concepts to architectural design. For instance, educators dealing with E&B issues have long been concerned with the “applicability gap.”[1] Although there are many potential reasons for this failure, one interpretation is that design studio education and E&B courses employ different pedagogical approaches. In studio, students structure their own problems and responses and apply concepts in the context of actual design problems. Studio critics supply a rich mixture of principles, concepts and rules of thumb [Schon D. A., 1987]. This approach has been termed “constructivist” [Driver R. and Oldham V., 1986; Schon D. A., 1983; Schon D. A., 1987]. By contrast, many E&B courses rely on what have been termed “instructionist” [Novak J. D. and Gowin D. B., 1984; Papert S., 1991] approaches that focus on transmitting more general facts and principles, and use traditional methods of instruction that rely on linear media, such as textbooks and lectures that support these goals.

Linearity of media is not a problem when the subject matter being taught is well structured, straightforward and fairly simple. However, as content increases in complexity, information can be difficult to convey with linear approaches. The advent of computer technologies enable new forms of nonlinear and multidimensional learning and instruction that are better suited to conveying complex E&B concepts in a way that they can be applied to design.

Educational computing in architecture and the research that accompanies it are not really new. However, most programs developed focus on instruction in Computer Aided Drafting and Design. While this represents a valuable and important application of computers in design curricula, it should not be the only use of computers for design education. Computing may also be used as a trigger, stimulant and opportunity for conceptual development in architectural education.

This paper discusses some problems with learning concepts in architectural education that can be transferred to design and particularly learning E&B concepts. It frames these problems in terms of the current debate in educational research between constructivist and instructionist approaches. Although this paper is primarily concerned with the application of theoretical issues of concept learning in architecture, these issues will be demonstrated within a specific context by utilizing a specific concept: the concept of "affordances" within the field of E&B. Finally, I propose a computer program that may suggest some solutions to the theoretical as well as practical issues that will be discussed in this paper.

Environment and Behavior

Architecture is defined as designing environments for people [Altman I., 1975; Broadbent G., et al., 1980; Duerk D, 1993; Johnson P., 1994; Kaplan S. and Kaplan R., 1978; Lang J., 1987; Lang J., et al., 1974; Perez-Gomez A., 1983; Rapoport A., 1982; Rowe P. G., 1991; Sommer R., 1983; Zeisel J, 1981]. The architectural environment in this context can be considered to consist of interrelated geographic, built, social, and cultural components that affect certain behaviors in consistent ways. Fundamental concepts of E&B are based on the assumption that people and their behaviors are part of a whole system that includes space and environment, such that behavior and environment cannot be empirically separated. According to E&B theory, human behavior cannot be evaluated without considering the environmental influence [Duerk D, 1993; Lang J., 1987]. Nor can the environment be evaluated separate from human behavior. E&B concepts are generally taught in lectures, but due to the complexity of environmental issues and the continuous change in human needs, the necessity to teach such concepts through lab exercises, lab discussions, and original field research has been gaining importance. However, there are several identifiable problems with E&B teaching:

(1) Despite the problems, such as the short duration of the courses and the number of students, E&B teaching is not supported by any external information technology aids to help integrate course materials for either the students or the teaching group;

(2) The structure of traditional instruction, with large groups, projects that need to be

graded and returned, etc., do not grant students as much individualized feedback as would be best. This is related to the above issue. The current system does not allow interactive learning at the students' own pace;

(3) While the courses introduce ideas of behavior and environmental capabilities and limitations in conjunction with examples in class, the students do not have the opportunity to generate hypothesis about complex situations, and to test and refine those hypothesis. The lack of this activity obstructs cohesive interpretation of facts, principles, and concepts taught in lectures;

(4) When students have to use E&B concepts in studio for the first time they are doing so without practice in applying them, and often without the help of their E&B instructor. Students report that this often makes transfer of ideas difficult and frustrating. Some instructors do give design assignments that target such activity, but this does not seem to be standard for such courses;

(5) A common problem in traditional architectural education in general, in E&B in particular, is compartmentalization. Conceptual areas that are highly related are presented in separate chapters, lessons, classes, etc. As a result, knowledge ends up being represented as if it were in separate compartments. When knowledge from across compartments needs to be combined later, for use, the representational basis for the conceptual combination is weak;

(6) Since architectural students tend to be visually oriented, they usually express their attitudes, preferences, and even criticisms graphically. This form of expression may inhibit verbalization which would make the comprehension of some concepts easier;

(7) Currently there is little opportunity for students to learn from the successes and failures of their and others' previous design projects. A wealth of data is available in the form of past design cases (both software and reports) nevertheless, very few attempts have been made to make this information available to current students.

What do students need to learn? How, and Where?

In order to teach architectural students to transfer their knowledge into the design process, it is necessary to investigate the conceptions of *how to learn, where to learn, and what to learn*. The first issue is *how to learn:* Should we focus on product by rewarding correct answers or on process by asking the student to imitate a model? The classical pedagogical approach emphasizes correct performance (i.e. errorless computations using geometric laws), but recent cognitive theories reject this approach. As Lochhead argues, [Lochhead J., 1979]: "We should be teaching students how to think; instead we are primarily teaching them what to think."[2] Lochhead contends that instead of focusing on the product, we should focus on the process. Another issue is *where to learn* : Should we teach in general domain-independent courses or in the specific subject areas within which the student will be tested? The classical approach is based on the idea of general transfer, that is, skills learned in one area can be used in different areas. However, research evidence[3] supports a preponderance of specific transfer, that is, knowledge learned in one area can be successfully used mainly in that area [Singley M. K. and Anderson J. R., 1989].

The third issue concerns *what to learn* : At the most optimistic level, students in the E&B courses need to learn how to design architectural projects by taking appropriate knowledge about human behaviors, capabilities and limitations into account. While many educational theorists would argue that this goal is best achieved by having students repeatedly design "behavior-conscious" environments, this is impractical due to the short duration of the courses, the number of students, and the resources available to support the course. Recognizing these limitations, the objectives listed by current instructors of E&B courses are more modest, such as: "The goal of the course is to give the student an appreciation of how knowledge of human psychological and physiological capabilities can be used to design effective environments" [Steinfeld E., 1992]; or "Introduction to principles and theories for the design of effective environments to human needs" [Zimring, 1994)]. A critical issue, though, is how to ensure that the principles and concepts introduced in the course will be *transferred* to the design situations students encounter in the future. In other words, they need to learn each concept in a manner that is comprehensive enough so that their understanding is useful in design and that they learn how to use that knowledge in design.

Approach Justifications

My approach integrates ideas about learning by doing and constructivist notions of learning. The constructivist theory of learning suggests that education is a creative human endeavor, and that its knowledge claims are not absolute [Driver R. and Oldham V., 1986]. Constructivism attempts to link teacher dominated instruction (instructionism), the traditional didactic model of education, to student-led discovery learning, the progressive model of education. Driver and Oldham describe constructivist teaching as being characterized by a number of steps, such as orientation, elicitation, and restructuring of ideas[4]. Constructivist methods emphasize the engagement of the student in the learning process and the importance of prior knowledge or conceptualization of new learning.

At an earlier time, educators and educational software designers assumed that they knew what was best for the students, what the educational preferences and real-world constraints were, and what the appropriate knowledge transmissions were in face of specific learning environments. Accordingly, the students were only passively involved in the learning process.

The tool I am proposing is a means of permitting students (the actual users of the tool) to participate more fully in the learning process that will have an effect on their comprehension of the concept. The underlying idea of my approach is *learning by doing* advocated by Schon [Schon D. A., 1983; Schon D. A., 1987], and Soloway et al. [Soloway E., et al., 1994]. I believe that the merit of my approach is that it carries user participation a step further along the learning process. In particular, this approach permits users who are often excluded from the active learning process to indicate their preferences. Through this form of participation, the participants are un-self-consciously able to express through actions (as well as words) their attitudes, preferences and criticisms, which they might find difficult to verbalize in other circumstances. Moreover, active participation appears to overcome most of the problems that have been experienced in using conventional learning environments, such as a lack of clarity of the goal, lack of motivation, the diversity of the users backgrounds and preferences, and new expectations of experienced users [Soloway E., et al., 1994]. According to Schon [Schon D. A., 1987], architectural design "must be learned by doing."[5] The student discovers that he or she is expected to learn, by doing. "...only learning which significantly influences behavior is self-discovered, self-appropriated learning."[6]

Accepting constructivism as a theory of learning leads me to two conclusions that are relevant for this study: students need opportunities to reflect in order to integrate their new knowledge with existing knowledge and; misconceptions need to be overcome that exist either prior to the formal introduction of the concept or develop as the student attempts to make sense of the concept.[7] Evaluation of existing designs with respect to the concepts being taught targets the first conclusion. This should facilitate the "integration of new knowledge" process. In addition, it should help motivate students. With respect to the misconceptions, the hypothesis testing methodology, with its focus on explaining (necessitating reflection) the reasoning behind a prediction, should help to highlight possible misconceptions.

AFFORDANCES

The tool I build utilizes the general methodology presented in the previous section in order to help students better understand the concept of affordances. This section provides some background information about the concept and presents reasons why the concept can help a designer.

The concept of affordances was first proposed by the ecological psychologist, Gibson [Gibson J. J., 1979]. Reacting to approaches which describe human actions as the result of cognitively intense activity based on simple perceptual cues from the environment, he suggested that many actions are directly perceivable from the environment. In other words, Gibson suggested that we can directly perceive opportunities for action in the environment. For instance, we perceive stairways in terms of their "climbability," a measurable property of the relationship between people and the stairs. The work required to climb a flight of stairs can be described by a U-shaped function relating work to riser height and tread width. Warren showed that people's visually-guided judgments of the climbability of different staircases reflect this function with great accuracy; people perceive the affordance of stairclimbing [Warren W. H., 1982] .

The concept of affordances is not a new one for design. Norman applied the concept to everyday artifacts. For instance, thin vertical doorhandles afford pulling, while "panic bars" afford pushing [Norman D., 1988] (Figure 1)

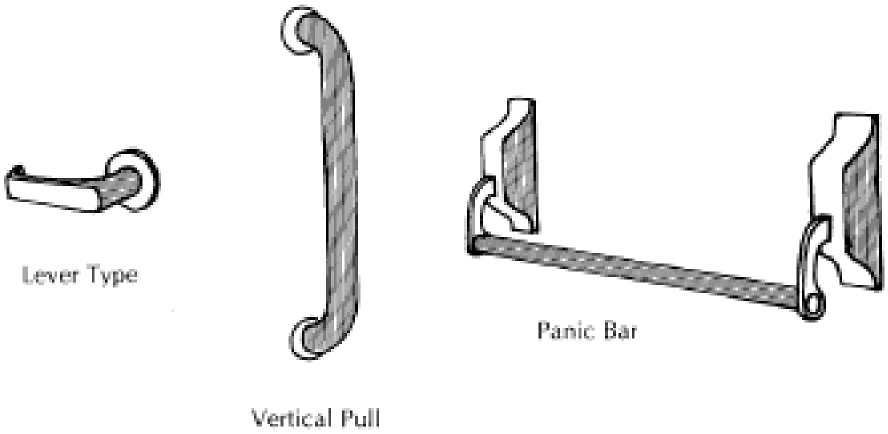


Figure 1. Different door handles suggest affordances for different actions

The interaction of an handle with the human motor system determines its affordances [Norman D., 1988] . When grasping a vertical bar, the hand and arm are in a configuration from which it is easy to pull; when contacting a panic bar pushing is easier. We can perceive affordances of doorhandles because the attributes that are relevant for grasping are perceptible . Furthermore, the course from perception to action seems to be a direct one, implying an ease of learning desirable for artifacts. However, perceptual information may suggest affordances that do not actually exist, while those that do exist may not be perceivable [Gibson J. J., 1979] .

Two aspects of the affordances concept are particularly important for a designer: 1) what creates an affordance and; (2) what makes the affordance perceptible to an actor. First, affordances exist due to an interaction between an actor's capabilities and characteristics of the environment. For example, a doorbell may afford ringing for an adult, but a child too short to reach it will not have the same opportunity for action. Similarly, a cat-door affords passage to a cat but not to me, while a doorway may afford passage to me but not to somebody taller. Affordances, then, are properties of the world defined with respect to people's interaction with it. It is clearly important that a designer knows which affordances exist for which users and be certain that all critical affordances are present for all users. Second, affordances exist whether or not they are perceived but it is because they are inherently about important properties that they need to be perceived [Gibson J. J., 1979].

While the previous design point focused on ensuring that affordances will exist when the actor needs them, this point focuses on ensuring that an actor will perceive appropriate affordances. What makes an affordance perceptible (i.e. how to ensure that a user will know what to do with the system) is an issue that a good designer will need to face. Besides these issues is how a user will map affordances to desired functions. It should be clear though, that, if the affordance cannot be perceived, then the function will not be completed whatever it may be.

Kirlik [Kirlik A., 1993] explored Gibson's concepts more deeply. He first showed that human behavior in a complex navigation task could be modeled successfully based on the

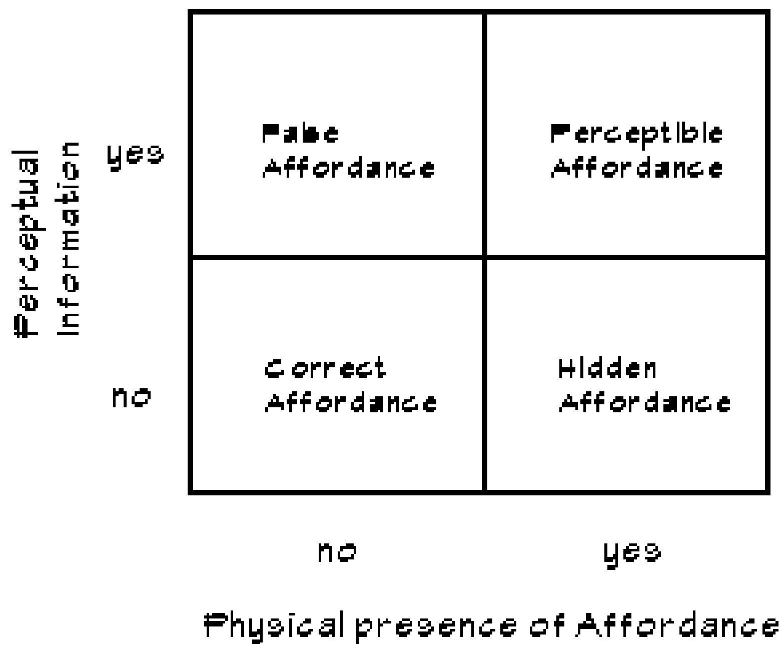
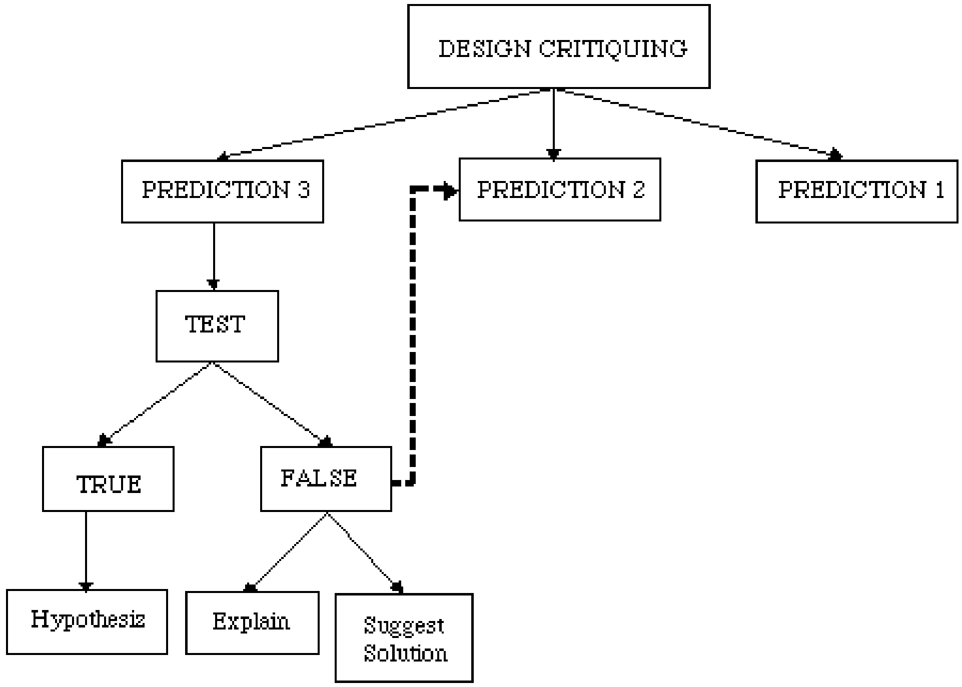


Figure 2. Separating presence of affordances from perceptual information

navigating "affordances" of the environment. Second, he presented a methodology called ecological task analysis that formalizes the notion that a one-to-one mapping between affordances in the environment and actions required by a user results in an ideal interface. This methodology was recently used to critically evaluate a computer game and to suggest improvements, most of which resulted in higher test subject scores [Kirlik A., 1993] . According to Lang [Lang J., 1987; Lang J., 1994], distinguishing affordances from perceptual information about them is useful in understanding "ease of use." Common examples of affordances refer to perceptible affordances, in which there is perceptual information available for an existing affordance. If there is no information available for an existing affordance, it is hidden and must be inferred from other evidence. For example, if in hospitals, individual buildings and major entrances are not clearly identified by perceptual cues, then exterior signs are vital to "direct, inform, identify, and define appropriate behavior."[8] If information suggests a nonexistent affordance, a false affordance exists upon which people may mistakenly try to act. For example, if the layout of a path is ill-designed, then the message can be very confusing [Arthur P. and Passini R., 1992]. " A wayfinding study in Montreal found that people who entered a pavilion through what clearly appeared to be a main public entrance found themselves in a corridor."[9] Finally, people will usually not think of a given action when there is no affordance for it nor any perceptual information suggesting it. From this point of view, separating affordances from the information available about them allows the distinction among correct, perceptible, hidden and false affordances (Figure 2).

Lang [Lang J., 1987] argues that the affordances of a physical setting are what it offers for good or ill because of the characteristics of its configuration and the material of which it is fabricated. "Architect Louis Kahn used the term "availabilities" and landscape architect Lancelot Brown "capabilities" in much the same way." From the architectural point of view, people make adaptations to their environments by structuring the surfaces of the environment around them. According to Lang [Lang J., 1987] , this arrangement, a result of their adaptation, affects all the interactions between them and the environment.

Figure 3. Critical Evaluation Process



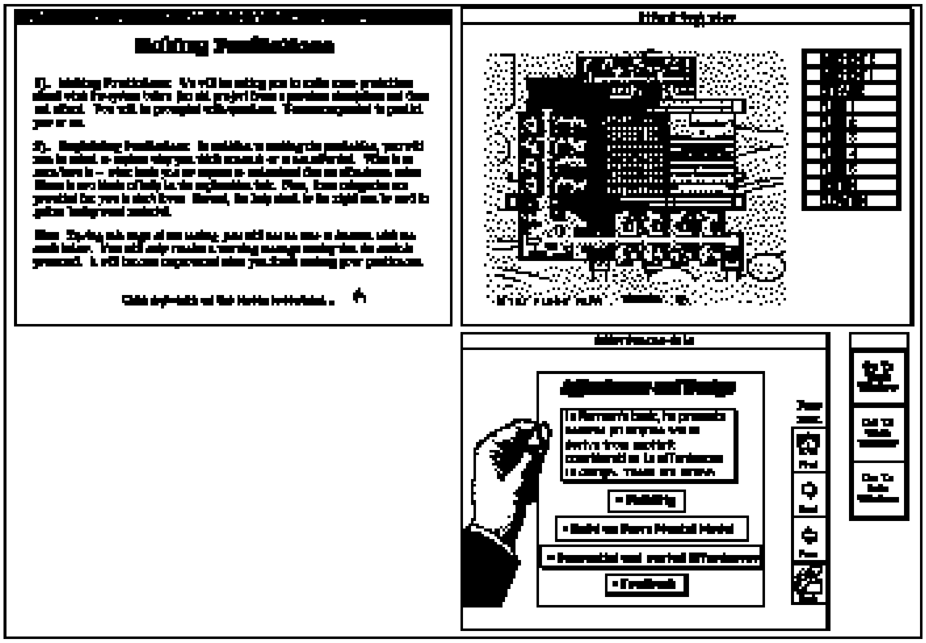
Any change in the built environment also affects the affordances of the world. In short, affordances exist in any built environment in various ways.

Gibson [Gibson J. J., 1979] focuses almost exclusively on affordances which may be seen. But affordances may be perceived using other senses as well. We can hear some affordances. Typical examples of affordances depend on attributes of the environment such as the size and orientation of surfaces; such attributes are those about which vision provides information. Sound conveys information for an affordance which can not be seen. From the architectural wayfinding communication point of view, Arthur and Passini [Arthur P. and Passini R., 1992] argue that entrances to certain buildings may be marked by a sound source. “This directional cue can be very efficient as long as it is not drowned out by background noises.....the solution is the reasonable one for buildings that are frequently used by the visually impaired population.”

Methodology - Design critiquing / hypothesis testing

What type of learning activities might be best suited for aiding the students in developing a deeper understanding of the E&B concepts and promoting their transfer to design?

Figure 4. Screen shot of different windows



Currently, the E&B course in Georgia Tech has many different components which focus on concepts and a single component (the project) which focuses on design. The introduction of a transitional component, critical evaluation of designs with respect to a single or small set of concepts, seems well suited as an addition to this course. I believe that critical evaluation will result in stronger understanding of concepts as well as in increased fluidity in invoking knowledge of concepts in design situations. In addition, one can argue that critical evaluation is a vehicle for the active participation of the students in the learning process. As Kozma [Kozma R. B., 1993] argues, learning is not a receptive response to instruction's presentation. Rather, learning is an active, constructive, cognitive and social process by which the learner strategically manages available cognitive, physical, and social resources to create new knowledge by interacting with information in the environment and integrating it with information already stored in memory [Shuell T., 1988] . On a philosophical level, this approach to instruction derives from the noncontinuity theory of concept learning which is based on an inductive reasoning method [Bruner J. S., et al., 1956; Trabasso T. R. and Bower G. H., 1968] . According to this view, concept learning is a noncontinuous or discontinuous process of constructing and testing

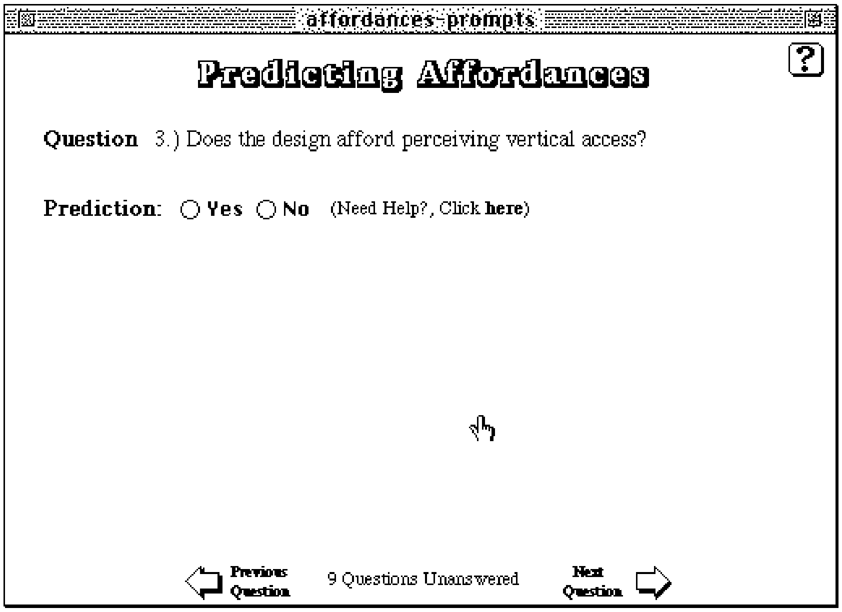
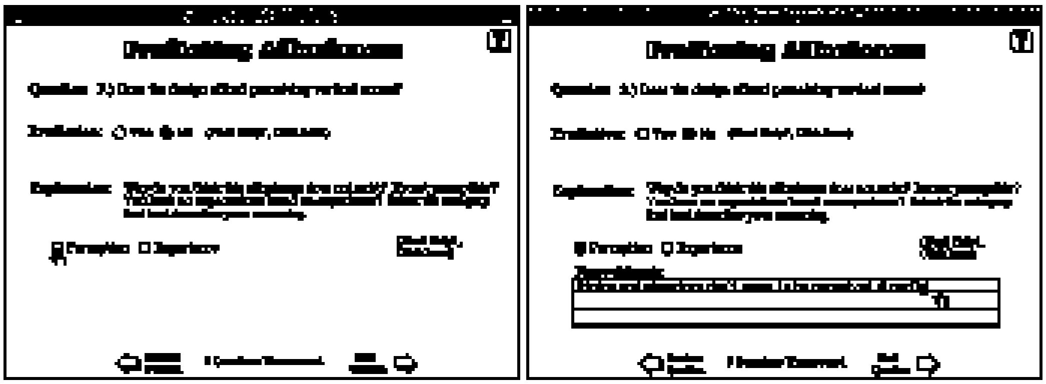


Figure 5. Prompting window

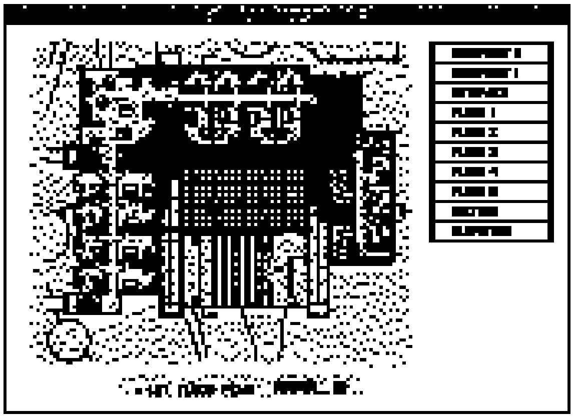
Figure 6. Phases of prediction making.



hypotheses until one works. Individuals at various points in time actively try to formulate rules. Once they find one that seems to work they stick with it until it fails to work. Thus, as seen in Figure 3, the user starts the critical evaluation process by making predictions about how an architectural environment will work.

In this noncontinuity view, thinking involves making a hypothesis and keeping it until it is disconfirmed rather than being a gradual learning of associations. Finding the correct solution is an “all or none” process [Bruner J. S., et al., 1956] . Based on this view, my

Figure 7. Case Window



approach is to try to get students into the hypothesis generation mode. Background knowledge is available on demand but is not forced on the user. In an effort to maximize transfer to the immediate design project, the designs to be critiqued will primarily be those from previous courses. Before testing his or her predictions, the user must describe his or her reasoning and explain the rationale behind it. If the prediction is wrong, the user is forced to reconcile the mismatch. Either he or she must revise the thinking that led up to the hypothesis or must recommend a design solution that would improve the design.

The Implementation of the Model

The system is built in Hypercard 2.2. The user interface for this system is comprised of three separate windows, each with a specialized purpose. The Information Window is used to provide the user with an interactive tutorial session which describes affordances, how to perceive affordances, and design principles to effectively use affordances. The knowledge area that the user is being questioned about in the Prompting Window can be linked to an affordance topic in the Information Window and supported by an illustrative example in the Example Window. The power of the system lies in the fact that the system does not operate as three individual programs; the programs are linked by command messages to function as a unit. This flow allows the entire system to cultivate the user's areas of inquiry, to support the users trouble areas, or to challenge the user's knowledge on the concept of affordances.

The underlying idea of my implementation is based on Software-Realized Scaffolding [Guzdial M., 1994] , and Media Theory [Kozma R. B., 1993] . Scaffolding, which supports or helps a user accomplish a task that he/she would not otherwise be able to do alone, is present in many forms in this implementation. More specifically, there are two forms of scaffolding used in this study - process scaffolding and articulation/content scaffolding. While the process scaffolding is similar to that which Guzdial presents, the articulation scaffolding is somewhat different [Guzdial M., 1994] .

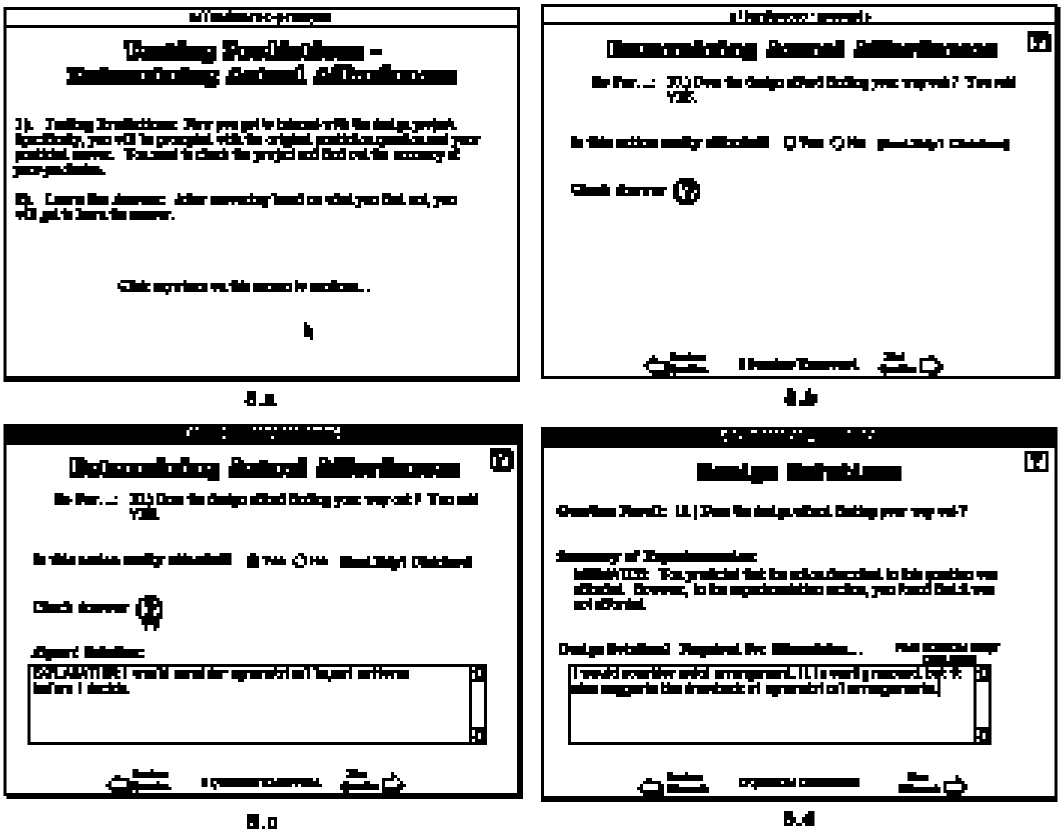


Figure 8. Sample Flow Through Critical Evaluation Process

In this proposed system, as seen in figure 4, the user is allowed to move freely through different screens and gather information about affordances.

The Prompting Window gathers the user's responses to various questions provided during the “prediction making” phase. See Figure 5.

Based on his/her prediction, the user is then asked to provide the reasoning behind his/her prediction as well as to elaborate it. Figure 6 demonstrates the different stages of the prediction making phase.

After the prediction is made, the user tests his/her predictions to determine the accuracy of this prediction by using the Case Window. The Case Window (Figure 7) is used to present the user with some plan examples that demonstrate effective or ineffective use of affordances. This window can operate in two separate modes. In the evaluation mode, the window's responsiveness is controlled where the user engages in a hypothesis testing process. In the case mode, on the other hand, the design projects selected in the Information Window (e.g. examples of student projects which violate a design principle that would otherwise have created a "good" design) are shown.

Figure 8 demonstrates the sequence of screens that guide the user through the prediction/evaluation task.

Process scaffolding is embodied in a sequence of screens so that it does not need to involve prompts (the questions) or separate screens (preventing premature closure on one stage of the task). An alternative would be to have the user simply pace himself/herself and type their answers directly into an answer form. The articulation/content scaffolding is embodied in the context sensitive help. At each stage of the process, the user is asked to articulate something about his/her understanding of the concept, "affordances". At each stage, it is possible that the user will not be capable of responding, most likely due to an insufficient understanding of what would constitute an answer. The context sensitive help guides the user in the direction of concepts, phrases, or even specific answers.

Implementation Issues

The following are some implementation issues that I am facing as the system is being developed and tested.

Feedback: When the program was first designed, it was based on asking the user to critique a specific design problem. As the user answers, his/her answers are then stored to a file for later evaluation. This method, while easy to implement, offers no feedback for the student. There are many different ways of attempting to deal with this problem. These are itemized below. In the end, I will probably use a combination of these approaches:

- Students could be allowed to work in groups where partners can provide the interaction that the program lacks. While this is an easy solution (minor additions to code, if any), it also comes with some problems. This method makes it harder to evaluate an individual's progress. Also, it may be difficult to know whether students are performing better because of the software or because of their groups. Finally, I am also faced with the task of finding more students to participate (i.e. to evaluate four people you need four people; to evaluate four groups, you need eight, twelve, sixteen or more people).
- The next option could be to allow the students to finish answering all the questions and then to show them the differences between their input and an "expert's" opinion. This provides some response and self-evaluation for the user; but it's questionable whether or not students would learn easier by simply comparing texts. Moreover, I need to enlist some outside experts who can evaluate the content of the system prior to experimentation with students.
- The system could infer information to provide to the user by parsing the input and determining various measures to describe the correctness or allowableness of the input. This method is good in encouraging and monitoring the user; however one has to choose which statistics to monitor (i.e. length, time of response, match with answer). The problem with this method is that all responses must be constrained in length or at least in the type of parsing and analysis performed for the sake of parsimony.
- Having the system pose multiple choices, fill-in-the blank, and short answer questions to which it can immediately respond is the final method I am considering. This method gives users immediate responses to their input. Then is the task of designing suitable questions at varying levels of difficulty.

Discussion

This study has two goals: to describe a learning tool for teaching architectural design concepts, and to situate this particular study in a general theoretical framework called Constructivism. It offers a comprehensive model for the constructivist vision of education in general, and for the use of computers in education, in particular. It also offers a model for the kinds of research I find insightful and beneficial to our understanding of learning and development, thinking, teaching, education, and the use of computers to facilitate these processes.

This study should not be viewed as a "controlled experiment". Pedagogical issues are quite complex, and one could formulate innumerable conjectures about the “real” source of students' learning. Nevertheless, I believe that this tool will allow the creation of a learning environment in which some integrated learning will take place.

In my view, a more complete understanding of the learning process can come through an integrative and accumulative process of experimentation and theory-building. This paper is intended as a contribution to that process. One can hypothesize, for example, that learning an architectural concept such as “affordances” and applying it to the design process could have been affected by factors related to: the student’s constructivist involvement ; the integrated learning principle; the learning by doing principle; and the design critiquing/hypothesis testing methodology.

One important point I want to emphasize is that each one these conjectures, when considered alone, would give only partial information about this study. By considering them together, and their interrelations, we can make use of an holistic approach, -knowledge, cognition and transfer, and development of learning environments.

Reflecting on Kozma's media theory [Kozma R. B., 1993] , it seems that we need to be able to answer the question "Why is this particular implementation dependent on the media it uses?" The theory suggests that answers to this question should describe matches between the symbol systems, processes, and technology characteristics of the task to be performed by the user to those of the media being used. In this case, the media of the learning environment and that of the subsequent transfer situations (the students' later design projects) are identical. In addition, the computer allows certain processes (e.g. data collection, scaffolding) to be utilized at a level that would be difficult if not impossible for a human. Finally, decisions about whether to allocate some tasks to the computer or to the experimenter/facilitator will be based on issues that are part of media theory.

This is an ongoing project, and I am working on making the program more reactive to the user and designing a better system of feedback for all users. In addition, expert evaluation is needed to either include explicitly in the system or to base subsequent decisions upon.

I have not tested the viability of this approach, or of the tool in particular, yet. Although the evaluation of the system has been considered all along, I have only just begun formalizing my evaluation approach. The methodologies for the evaluation include artifact analysis, clinical before and after interviews, test scores on particular questions from final exams, log file analysis, questionnaires and surveys. Once the parameters of the study are finalized, the study can be assessed by using several factors such as: (1) What is the reliability of this study? This can be achieved when errors and biases are eliminated and the operation is repeated with the same general results; (2) What is the construct validity of the research? Are correct operational measures established for the concepts being studied? Is active participation the construct variable?, is it hypothesis testing, scaffolding, etc.?; (3) What is the internal validity of this study? Does the information provided cause any effect on the learning process? Does active participation cause any effect on concept learning? or both?; (4) What is the external validity of this study? Are the findings and conclusions generalizable to this particular research study or to other similar kinds of projects?

Lastly, there are two main issues involving design interaction that needs to be addressed. The first is whether instructors will be part of the learning process or whether we will let the tool stand by itself. Second, it is necessary to decide whether the subjects should be tested before or after the session or at both times.

While this effort deals only with a small part of the design education process, I believe it does explore a number of significant issues concerning educators in architecture as well as the development of computer-based teaching tools, and suggests a solution for addressing some of these concerns.

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