not white

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Integrating Cognitive Processes into Beginning Design Education

abstract
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One critical goal of design education is facilitating the movement of students from beginner toward expert. Typically, design educators think of this transition in terms of improving student performance over a course of study. This conception raises a question: what is the most effective means of improving student performance and thus moving an individual toward expertise? The answer to this question is a point worthy of argument in schools of architecture and amongst individuals. However, the purpose of this paper is to expose an important and often overlooked aspect of this debate – the role of cognitive processes in the development of design expertise.

Cognitive processes are simply defined as the operating procedures and regulation of the mind. Understanding cognitive processes, such as memory and perception, is as undeniably important as it is overlooked in the design of instruction and curriculum with schools of architecture. Many educators see these processes as the essential underlying determinants of learning and therefore critical building blocks for teaching and learning. This paper describes a set of cognitive processes derived from research in the field of cognitive psychology. Each set of processes is explained and then theoretically applied to learning contexts within design education. For organizational purposes, the cognitive processes have been categorized to create five groups that include: 1) acquiring design information, 2) utilizing design knowledge, 3) design thinking, 4) solving design problems, and 5) designer's expertise (See Table 1 below). Each section of this paper describes a different category and provides examples for putting the processes into teaching practice.

The paper session at *Not White: Diversity in Beginning Design Education* provides participants with an understanding of cognitive processes and their application to design education. Session participants will find that by increasing their knowledge about mental functioning they will also uncover a need to reflect upon their own teaching methods and course structure – a refreshing and constructive endeavor.

TABLE 1: COGNITIVE PROCESSES APPLIED TO DESIGN EDUCATION

DESIGN EDUCATION	COGNITIVE PRINCIPALS	APPLICATIONS
***Acquiring Design Information*–** Processes & methods for obtaining and securing information believed important for designers, developing a foundation	***Encoding/Practice/Elaboration*–** Encoding information into memory. Using practice and elaboration to meaningfully strengthen memory	***Teacher* –** Provide sources of info, set rhythm of information presentation ***Beginner* –** Practice and make meaning from incoming information
***Utilizing Design Knowledge*–** Recalling and discerning important information, creating cognitive links to guide thinking	***Retrieval/Context/Memory* –** Ability to remember important information and solutions, situating knowledge in context	***Teacher* –** Help students recall viable pieces of information for use ***Beginner*** – Connect/Apply knowledge to broad issues
Design Thinking – Learning to think like a designer, wisely utilizing information and knowledge for designing	***Schemas/Scripts* –** Knowledge representations that are abstracted and generalized based on experience and knowledge	***Teacher*** – Determine student's preexisting schemas/scripts ***Beginner*** – Reflect professional knowledge representations
***Solving Design Problems* –** Learning to find problems and develop solutions, more effective and efficient problem solving	***Finding/Representing/Solving*** – Identifying problems, using knowledge and experience to represent and solve problems	***Teacher*** – Pose interesting problems, facilitate process and solutions ***Beginner*** – Work on problem finding and representation, be reflective
***Designer's Expertise* –** The role of expertise in making decisions and solving problems, the importance of experts	***Characteristics/Development*** – Features that differentiate a novice from an expert, becoming	***Teacher*** – Introduce strategies, create situations for developing expertise ***Beginner*** – Familiarization/Practice expert strategies

INTRODUCTION

"People's knowledge of their own learning and cognitive processes and their consequent regulation of those processes to enhance learning and memory are collectively known as *metacognition*" (Ormrod 1999, 318). Metacognition is like the manager or coach of a person's cognition and learning. By guiding information processing and monitoring learning, metacognition eventually heightens awareness, deepens knowledge, and contributes towards expertise. Studies show that the more metacognitively adept students are, the greater their learning and achievement is likely to be (Wittrock 1994). Metacognition is also very important for achieving expertise because it helps individual's become better problem solvers.

To achieve expertise an individual must learn to identify and represent problem solutions quickly and accurately (Magliaro 1988). Since architectural design is fundamentally problem solving (Rowe 1998) and problem identification and representation is central to problem solving (Kaplan 1976) then it seems imperative for architecture students to utilize metacognition so they can move towards expertise. In terms of instruction, initial presentations of information, which individual's can learn more easily learned in the beginning of their learning process (Blackburn 1936, Newell and Rosenbloom 1981), is extremely valuable because initial learning serves as the foundation for future know how. As Kaplan (1976) says, "everyone represents problems in terms of previously learned elements." Therefore, previously learned elements are metacognitive catalysts in the construction of knowledge structures that will eventually determine the expertise of professional problem finders and solvers (Fosnot 1996).

The purpose of this paper is to help teachers design instruction that A) effectively moves their students from novices to experts and B) increases metacognition. A theoretical application of principals derived from literature in the field of cognitive psychology and related to beginning design education helps the paper achieve its purpose. Four categories organize the cognitive principals and illustrate their application to beginning design education. Table 1 shows the four categories. Each section in the paper corresponds to one of the categories and provides implications for putting the principals into teaching practice. (Please see the Table shown with this paper's Abstract.)

ACQUIRING DESIGN INFORMATION

In recent years, educational psychology has shifted from a behaviorist to cognitivist psychological paradigm. This shift is leading to new memory research and experimentation. The following sections focus on human memory and the way information gets into the memory system that we call the mind.

MEMORY SPANS

In the 1960's a theory known as short-term memory was developed (Waugh and Norman 1965, Atkinson and Shiffrin 1968). This popular theory claims that information is stored in a limited capacity for a short period until it is rehearsed and committed to long-term memory. The problem with short-term memory is rapid forgetfulness or quickly forgetting something before committing it to long-term memory. The problem results from a constant stream of incoming information stressing the mind's limited storage capacity consequently pushing older information out. Rapid forgetfulness led early psychologists to conclude that the difference in short-term memory and long-term memory is mental capacity. This research has several implications for beginning design students encountering enormous amounts of new information over a relatively short period.

IMPLICATIONS

Teachers should carefully monitor the quantity and rate of information presented to beginning design students. Too much information, too fast is counterproductive and stresses the student's mental capacity leading to forgetting and confusion. The philosopher and educator Alfred North Whitehead encouraged teachers not teach too much information because it leads to "the passive reception of disconnected ideas, not illuminated with any spark of vitality" (Whitehead 1949, 14). Typically, when students feel overwhelmed or crushed by excessive information they lose their vitality to learn and "shut down" many mental functions. Teachers should reanalyze the total amount of information they expect beginning design students to know and then teach only quintessential information and concepts. As Whitehead says, "do not teach too many subjects but what you do teach, teach thoroughly" (14).

PRACTICE AND MEANINGFUL ELABORATION

Information that is stored and committed to the mind leaves traces of its whereabouts in the memory system for recall later. Recalling information from traces of memory is called activation (Anderson 2000). Psychologists Ratcliff and McKoon (1981) showed that the activation level of a memory trace undergoes general strengthening through repeated *practice*. Numerous researchers (Pirolli and Anderson 1985, Newell and Rosenbloom 1981) show that practice increases strength and speed of recall – in particular when it is thorough and saturating. Combining practice with *meaningful elaboration* or processing furthers its effectiveness (Anderson and Bower 1972, Stein and Bransford 1979) especially when a learner attaches some type of extended meaning to it, either directly related to the practice subject or not (Slamecka and Graf 1978). For example, if you are trying to remember a person's name you can first say the name repeatedly until it is committed to your short-term memory. Next, you can practice remembering the person's name again for a week or until you have strengthened its trace and committed it to long-term memory. Finally, if you connect the person's name with something of meaning to you, like say your uncle's name or your favorite athlete, then through meaningful elaboration you will further strengthen your ability to remember and recall the person's name with speed and ease.

IMPLICATIONS

Expert designers seem effortless in their ability to derive inspiration from their experience and memory. This is because experts have years of practice and meaning associated with their craft. For beginning designers, the critical ingredient for the development of this expert ability is practice (Bloom 1986, Newell and Rosenbloom 1981, Shiffrin and Dumais 1981). To become an expert, beginning design students should practice remembering things like design principals and examples of "good" design so that they can easily and quickly trace down and utilize these things for designing. Some researchers (Hyde and Jenkins 1973, and Postman 1964) have shown that whether or not one intends to learn, the level of processing and practice will determine the amount of information remembered. In other words, remembering a project or task that is meaningful in some way is more likely whether the learner wants to remember it or not. For beginning design teachers, this means giving students ownership and opportunities to make meaning for themselves in their projects. Allowing students to choose the topic or method of representation for their project is one way to encourage depth and thorough, elaborative processing of information.

UTILIZING DESIGN KNOWLEDGE

The previous section has focused on the processes involved in getting information into memory and readying it for retrieval. The following sections will discuss retrieving information from memory.

RETRIEVAL AND INTERFERENCE

A study by Barnes (1979) shows that retrieving information is dependent upon its original method of acquisition, processing, practice, and contextual underpinnings, all things that lessen and slow over time. Anderson (2000) adds that time is not the only variable affecting memory recall. He suggests that *interference* caused by conflicting memories and thoughts influence retrieval. Interference happens when an idea becomes cloudy by competing ideas or distractions. This cloudiness can lead to forgetting where information is stored and confusion about what might or might not be an accurate recollection. In short, interference is one of the single most prevalent factors in retrieving information from memory.

IMPLICATIONS

For beginning design students, the new challenges of university life will interfere with memory traces leading to confusion between new and old information. To avoid interference the teacher may allow students to share their past learning experiences so that prior knowledge is explicitly reinforced rather than left to sit silently and possibly interfere in the construction of new knowledge. In addition, thoroughly explaining student-learning expectations will help to clarify objectives and leave less room for interference. Finally, encouraging students to describe the basis for their decision-making can expose possible interfering information and allow the teacher to intervene in the learning process.

CONTEXTUAL EFFECTS

Using the context that formed the memory as an activator or cue can help in retrieving some memories. Experiments by Smith, Glenberg, and Bjork (1978) have shown that contextual physical elements like a particular room or driving route get associated with memories, and that providing contextual physical elements to these subjects again will improve their memory (Anderson 2000). Studies by Teasdale and Russell (1983) tie an individual's mood to the ability to recall information. In other words, sad memories are more easily remembered when an individual is sad. Learning that is linked to emotional and physical states, known as state-dependent learning, shows people find it easier to recall information if they can return to the same emotional and physical state they were in when they learned the information.

IMPLICATIONS

Seasoned designers can call on experience to quickly understand the context of a site, for example, and determine a fitting design for it. A beginning design students has very little to relate to in terms of examining a site's context for relevant factors. The beginner finds it difficult and more tedious to come to the same conclusion as the expert in terms of site characteristics. One way to help beginning students effectively analyze context is to take them to a variety of sites and simply talk about the site's mood or spirit. Discuss the process of site evaluation and analysis while on site. Learning about the site while participating in the context of the site itself will deepen processing and help students to remember how to analyze a site when they arrive to investigate their client's property later as professionals.

SOLVING DESIGN PROBLEMS

Designers, like everyone, face hundreds of problems daily. They range from simple like purchasing blueprint paper to elaborate like achieving sustainability. Virtually all problems range in complexity because "all cognitive activities are fundamentally problem solving in nature" (Anderson 2000, 240). The basic argument is that human cognition is always purposeful, directed toward achieving goals by removing obstacles and solving problems (Anderson 1983, Newell 1980, Tolman 1932). A "problem" is any situation that exists when a current state differs from a desired state (Bransford and Stein 1984). The span between current state and desired state determines the nature of the problem. Knowing the characteristics of past solutions will suggest appropriate strategies for solving a similar problem faced in the future. Ultimately, solving a problem depends upon the knowledge, wisdom, skill, and experience of the person or group charged with solving it.

Most problems are either well defined or ill defined based upon the structure of the problem and the amount of resources needed to solve it. A well-defined problem is solved using a nearly guaranteed strategy and has only a few known solutions. For example, a slope calculation that uses a basic equation will yield a precise answer. However, an ill-defined problem, according to Kitchener (1983), has more than one accepted solution and no universally agreed-on strategy for solving. Worldwide ecological problems, such as global warming, provide a good example of an ill-defined problem. The first step in solving problems resides in an individual's existing knowledge and ability to learn about a problem.

PROCEDURAL KNOWLEDGE AND OPERATORS

Declarative knowledge is explicit knowledge of facts that we can report and of which we are consciously aware. Procedural knowledge is knowledge of how to do things and is often implicit (Anderson 2000). In terms of problem solving, procedural knowledge is like puzzle pieces lying in some stage of completion. Solving the puzzle happens when each piece fits into the next appropriate piece. Kohler (1927) and other more recent studies suggest most problem-solving activities have three essential elements. These three elements are: 1) goal directed behavior, 2) reorganization of the goal into a set of sub goals or objectives, and 3) the application of a successful operator. An *operator* is an action, like putting together two puzzle pieces, and is a function of procedural knowledge. A successful sequencing of operators provides a solution to a problem.

Acquiring new operators and procedures happens in three ways. The first is discovery. For example, we may learn a new shade tree grows in our backyard by trial and error. In this way, we have discovered a new operator for solving the problem of shade in our backyard. The second is having someone tell you about a possible operator. For example, a teacher can tell a student how to calculate live loads and then expect them to do it. The third method for acquiring operators and new procedures involves observing someone else. This method involves giving examples, role modeling, and making analogies. Analogies involve both noticing that a past problem solution is relevant and then representing the elements from that solution to produce an operator for the current problem (Anderson 2000, Gick and Holyoak 1980). Reed and Boldstad (1991) have demonstrated that telling or showing someone how to solve a problem is not always as straightforward and efficient as it seems. Their findings indicate that subjects given examples rather than direct instruction before a problem solving exercise are more likely to solve the problem effectively. However, the combination of instruction and examples doubled the odds of subjects solving the problem. Beginning design teachers should give students models and examples in addition to instruction whenever possible to help students develop successful operators.

PROBLEM IDENTIFICATION

Identifying a problem is one of the most difficult and challenging aspects of problem solving. Identification requires creativity and persistence, yet a willingness to ponder a problem for a long time without committing to a solution too early in the process (Hayes 1988). Students face several obstacles when trying to identify a problem. One obstacle for problem identification is the rarity for people to engage in the habit of actively searching out problems. Most people see problems as something to avoid instead of define and solve. Another obstacle to successful problem identification is a lack of relevant background knowledge. For example, solving or even identifying problems of plant propagation are extremely difficult without a great deal of preexisting knowledge about botany and horticulture. A study by Getzels and Czikszentmihalyi (1976) found another obstacle to problem finding. Their study shows most people do not take enough time to reflect carefully on either the nature of a problem or its solution. Viable problem identification allows the problem solver to represent the problem clearly while selecting potentially successful operators.

PROBLEM REPRESENTATION

According to Anderson (2000), the representation of the problem has significant effects upon solution. Problem representation is the mind's ability to picture and display the identified problem. Studies by Kaplan and Simon (1990) and DeGroot (1965) have shown that viable representations of problems are critical in selecting and applying operators. Even with the necessary knowledge, an inappropriate problem representation can often cause students to fail to solve a problem often frustrating teachers (Anderson 2000). Teachers can uncover their student's existing knowledge and aid in problem representation by using an external or tangible form of representation. Several psychologists suggest representing the problem graphically by using drawings, graphs, visuals, and equations to help reduce the cognitive resources needed to remember problem criteria and constraints. External representations help students see the entire problem, identify potential operators, and illuminate holes in procedural knowledge.

IMPLICATIONS

It is important for beginning design teachers to have professionals discuss and even demonstrate their work with students. This allows beginners to watch experts at work and observe the expert's procedure. Watching an accomplished designer work and think aloud permits a glimpse into both the procedural and declarative knowledge utilized and stored in the mind of the designer. In this scenario, the beginning student may need to have even seemingly obvious things explained to them. This is because of the student's lack of preexisting knowledge and the expert's inability to articulate what they are doing because the basis of their process knowledge is procedural and thus likely implicit. In this case, the expert may fail to realize that not everyone knows what he or she knows. Johnson (1988) says even highly skilled experts often find it difficult to describe what it is they know about a body of knowledge, and consequently may be unable to teach or reflect upon their procedures.

The beginning design teacher should assume nothing, instead explaining and demonstrating whenever possible. While it is likely that students will learn without such effort on the part of the teacher, the intentions of these suggestions is to increase the efficacy of *learning for expertise*.

DESIGNER'S EXPERTISE

Developing expertise is a function of practice and meaningful experience solving problems. Typically, experts are better problem solvers than novices are because of their discipline-specific experience, preexisting knowledge, and cognitive resources (Glaser and Chi 1988). Anderson (2000) says that through extensive practice we can develop the high levels of expertise that are particularly important in dealing with ill-defined problems. Studies by Ericsson (1996) contend that developing skills and intellect at an expert level takes about five to ten years of practice and sometimes more. The time it takes to develop expertise is dependant upon numerous factors, notably the effectiveness of teachers and the maximization of learning opportunities.

DEVELOPING EXPERTISE

Berliner (1994), Bloom (1985), and Ackerman (1988, 1992) propose that developing skills and expertise happens both consistently across disciplines and in stages. For Bloom, these stages correspond to the years a novice has spent working in a particular discipline. For example, an architect that has been working for 20 years exhibits more expert characteristics than one working for only 2 years. For Ackerman, the stages of expertise are a reflection of skills acquired and degree of skill automation. In Ackerman's case, this means despite the number of years the architect has been practicing, expertise is a function of acquiring and efficiently using knowledge and skills. However, regardless of the difference in developmental concepts, most research agrees that the more one practices the better one becomes, regardless of initial talent and ability. Ericsson, Krampe, and Tesch-Romer (1993) suggest that extended practice counts more than inherent ability stating, "our review has uncovered essentially no support for the fixed innate characteristics that would correspond to general or specific natural ability" (399). Thus, even though a perceived innate talent may help a student develop expertise, it in no way guarantees an expert. Bloom (1985) supports this saying, " no matter how precocious one is at age ten or eleven, if the individual doesn't stick with the talent development process over many years, he or she will soon be outdistanced by others who continue" (538).

IMPLICATIONS

Berliner (1994), Glaser and Chi (1988), and Glaser (1987) have outlined characteristics common to most experts. A brief summary of these characteristics hold that experts: 1) excel only in their own domain or field, 2) process information in large units or chunks, 3) hold more information in working memory and long-term memory, 4) are faster than novices at doing tasks and solving problems, 5) represent problems at a deeper level, 6) spend more time analyzing a problem, and 7) are better monitors of their own performance.

Although these characteristics reflect years of dedication to a discipline, beginning design teachers should keep these characteristics in mind during the design of instruction and projects. For example, if teachers stress interconnectedness and big concepts then they will help students to manipulate large units of information without presenting too much information. By stimulating thinking and encouraging practice teachers can fuel their students' memory systems. Charettes or quick design projects can increase speed – especially if followed by thorough debriefing and reflection. Focusing on problem representation affords teachers opportunities to guide novice students to think deeper about how to represent a problem. Encouraging students to take extra time identifying and analyzing problems reinforces this characteristic of experts especially if teachers show students why slowing down can be beneficial to solving a problem. Accompanying these exercises with useful examples and feedback will increase the quality and quantity of student practice thereby helping them to become experts.

CONCLUSION

Applying the concept of metacognition is the responsibility of the student while encouraging metacognition is the role of the teacher. Nowhere is this more important than in beginning design education. For it is there, that new students must learn masses of new information, successfully remember and process that information while at the same time using it to design. A general application of cognitive psychological research to beginning design education suggests that teachers who structure projects and exercises to help students see the value in reflecting and regulating their own mental processing will speed their student's movement toward expertise. Especially, when providing opportunities for students to deepen processing, attach meaning to new information, practice, and discuss expert procedures. In conclusion, it takes a great effort to become a professional architect or landscape architect but it also requires mindful teaching sensitive to students' learning. Designing instruction based on valid, reliable cognitive principals can empower both student and teacher.

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