

Investigating the Effectiveness of Mental Imagery Strategies in a Constructivist Approach to Mathematics Instruction

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With a paradigm shift away from a behaviorist conceptualization of learning and problem solving toward a cognitive point of view, a trend toward investigating constructivist aspects of learning has emerged in the educational community (Ashcraft, 1989). Consequently, many researchers have explored the efficacy of incorporating metacognitive strategies into the instructional environment in order to give students an effective meaning-making framework for learning and problem solving. This inquiry into “thinking about thinking” has revealed the fact that successful learners are those who possess and regulate a repertoire of strategies. Among the strategies of interest to educational researchers are those associated with mental imagery. Mental imagery and its concomitant representations have been demonstrated to play an important role in dynamic problem solving (Sadoski & Paivio, 2001). However, research investigating the effects of mental imagery on mathematics instruction and student learning has lagged behind research in other types of learning strategies. This is unfortunate in light of the fact that research in visual imagery has been shown to enhance the type of deep level conceptual connections that facilitate both recall and comprehension of verbal learning (Craik & Lockhart, 1972). It follows that the conceptual connections that result from imagery in verbal learning will also facilitate the construction of conceptual connections in spatial learning and problem solving. This paper will focus on the theoretical framework that supports targeting imagery instruction from a constructivist perspective. Findings from a preliminary investigation of the effects of imagery strategies on problem solving will also be presented.

Representing one of the first topics studied by experimental psychologists, the origin of mental imagery can actually be traced back thousands of years, since it played a central role in the higher education of both the ancient Greek and Roman scholars (Ashcraft, 1989; Higbee, 1979; Khatena, 1984; Sadoski & Paivio, 2001). Because rhetoric, or the art of public speaking, required a great deal of memorization, these ancient rhetoricians relied heavily on Aristotle's "Model of Memory" (Wittrock, 1988). This model emphasized putting the points of a speech in linear order and then representing each point with a familiar object that was easily retrievable from memory. Although mental imagery remained an integral part of the educational process for thousands of years, it eventually became relegated to a position of relative obscurity after the period of the Renaissance when an emphasis on rationalism became more pervasive. Its consignment to the realm of the "primitive and prelogical" (Speidel & Troy, 1985) was even more firmly established during the behaviorist revolution when the study of mental imagery was considered unscientific and was, for the most part, abandoned as a topic of interest and research. However, with contemporary emphasis on the individual's cognitive construction of his/her own reality (diSibio, 1982; Ginsburg & Oppen, 1988; Rosenblatt, 1988; and Wittrock, 1988), a renewed interest in mental imagery has emerged. Consequently, with mental imagery no longer relegated simply to the realm of the aesthetic, many educational researchers have begun to view mental imagery as a fertile arena of investigation.

Because of the complexity of the imagery process, a specific definition for mental imagery is one that has been vigorously debated among researchers over the years (Block, 1981; Dennett, 1981; Holt, 1972; Kosslyn, Pinker, Smith & Shwartz, 1981; Paivio, 1986; Piaget & Inhelder, 1971; Sadoski, Paivio & Goetz, 1991). Simply defined, however, mental imagery is the act or power of forming mental pictures of objects or events not present to the eye that can then affect later recall and comprehension. Serving as a kind of mental blackboard, mental imagery plays an important role in both the understanding and memorability of concepts. The “mental blackboard” description of the mental imagery process reflects its contemporary conceptualization as an active and dynamic information-processing event that can aid the learner in problem-solving activities, especially those that are representative of unfamiliar or novel situations.

Mental Imagery as a Constructivist Act Much of the educational and psychological research that has arisen from the cognitive revolution, including that associated with mental imagery, has specifically focused on the kind of mental representations individuals *construct* during the learning process.

Emerging from a cognitive paradigm, the constructivist theoretical framework is representative of the contemporary notion that learning is an active, meaning-making experience in which meaning is constructed from the existing store of knowledge that learners bring to the learning task in conjunction with newly acquired knowledge, such as that gained through instruction.

Within the field of psychology, constructivism provides a framework for researchers concerned with investigating the mental processes involved in learning and memory and how mental representations are constructed (Ashcraft, 1989). In the field of education, contemporary researchers have rejected the notion of learning as a series of discrete skills and have turned to questions that address the learner's active role in the learning process. From these two perspectives, research within both psychology and education has acknowledged the role of mental imagery within a constructivist notion of memory and learning. Central to the notion of constructivism are the three subprocesses that are subsumed within the constructive process (Spivey, 1987). These include the *organization* of concepts according to a structure existing within the learner's prior knowledge, the *selection* of concepts based on some principle of importance, and the *connection* of concepts through the construction of inferences or elaborations. It is the subprocess of constructing connections that is of particular interest to researchers who investigate the effects of mental imagery. This interest is reflected by the fact that the elaborative links that a learner constructs as he/she problem solves may actually take the form of mental images that reflect concrete episodes or concepts.

The construction of imaginal elaborations that serve to connect concepts with pre-existing schematic stores also have direct implications for Craik and Lockhart's depth of processing framework (1972). The theoretical position behind the notion of more elaborate and complex rehearsal in relation to learning asserts that there are two major kinds of rehearsal, each with different effects on storage. In Craik and Lockhart's view, *maintenance rehearsal* (or Type I rehearsal) merely maintains information at a particular level in the memory system, without storing it deeply. However, *elaborative rehearsal* (or Type II rehearsal) uses the meaning of the information itself to help store and remember it, thereby storing the information more deeply in the memory system. The sort of meaningful, elaborative processing facilitated by mental imaging corresponds to a deep encoding of the information. As a consequence, information that is rehearsed elaboratively through the construction of mental images should be retrieved, or remembered, more efficiently (Sadoski, 1983, 1985; Sadoski & Quast, 1990). An important theme in the depth of processing framework that directly relates to the concept of mental imagery as a constructivist act is the assumption that the mental activities in which a learner engages *during* processing, such as the construction of inferences or elaborations based upon specific concepts, can be predictive of later ease of retrieval.

Additional theoretical support for investigating the effects of mental imagery strategies on learning and problem solving is found in Dual Coding Theory (Paivio, 1971, 1986; Sadoski & Paivio, 1994, 2001). This theoretical construct posits the notion that cognition is comprised of two alternative mental coding subsystems used for symbolic representation of meaning. The verbal subsystem is used to process the type of verbal information reflected by words/text. Paivio and Sadoski contend that words are encoded, and later retrieved, *descriptively* in terms of their verbal attributes. However, ideas that denote nonverbal, concrete information are encoded and retrieved *pictorially* in terms of their imaginal attributes. Consequently, the nonverbal subsystem is specialized for processing the type of spatial information reflected in mathematical learning. An integral component of Dual Coding Theory reflects the relationship between the verbal and imagery subsystems and multiple sense modalities. That is, learning is experienced and perceived through the stimulation of multiple senses that reflect visual, auditory, haptic/kinesthetic, gustatory, and olfactory modalities. From the perspective of Dual Coding theory, learning is explained through direct interconnections between modality-specific mental representations within the verbal and imagery subsystems. Learners can switch from one sense modality to another within a subsystem (e.g., reading to listening) or between subsystems (e.g., reading to imaging). Self-monitoring one's cognition can also take place within and between subsystems through self-regulatory speech or mental imaging of alternative scenarios.

The Sensory Activation Model (SAM) Imagery Strategy Although a strong rationale for integrating mental imagery strategies across the curriculum is well established, few teachers avail themselves of this

invaluable instructional/learning tool. Unfortunately, when mental imagery strategies are utilized in classroom, the prevailing instructional protocol reflects a guided imagery format in which teachers assume the responsibility for the imaging process by modeling their personal images for students to observe. A second weakness in the existing instructional protocol reflects a single modality imagery approach in which only the visual sense is activated when students are instructed to *see* a picture in their mind. This type of single modality instruction ignores the analysis of mental images that reveals visual, auditory, haptic/kinesthetic, gustatory, and olfactory modalities.

In a study designed to investigate the effects of instruction in a multi-sensory imagery strategy on 5th graders' learning and prose processing, students received instruction in the SAM/Sensory Activation Model strategy (Douville, 1998). As shown below, the SAM strategy is based upon a model of imagery instruction that incorporates the activation of multiple sensory modalities within the imagery process. When compared to control groups of 5th grade students who either received no imagery training or who received mental imagery instruction that incorporated the activation of only a visual modality, posttest measures revealed that the SAM group students constructed significantly more images when reading narrative text than their visual modality control group peers (Table 1). Additional finding emerged from the qualitative analysis of exit interviews with the teachers and students who participated in the study. Out of a total of eighteen 5th grade teachers, only one of the teachers had instructed students in imagery strategies previous to the study, and the instruction reflected only visual modality activation. However, it was in the voices of the students themselves that the most compelling evidence for multi-sensory imagery instruction was revealed. Describing mental imagery as "having a video camera in my brain" and "going to a movie in my head" simply made reading and learning more fun for the participating students.

The Connection Between Mental Imagery and Mathematical Problem Solving

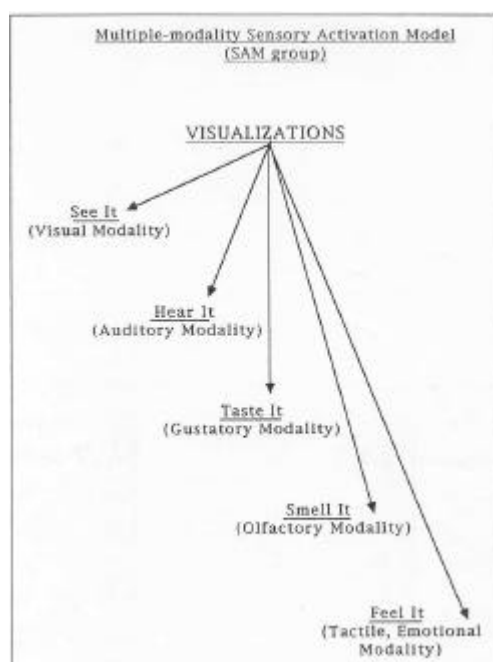
The National Council of Teachers of Mathematics (NCTM, 2000) emphasizes the importance of the role that language plays in helping learners make connections between their existing knowledge and the abstract symbolism of mathematical concepts. However, when mathematics is taught as a discrete series of computational skills, the authentic nature of mathematics as a real-life problem solving activity is ignored. It is incumbent upon mathematics teachers to assist learners in making connections between mathematical concepts and the existing knowledge students bring to problem solving in ways that concretize learning tasks. Because mental imagery strategies have been demonstrated to assist students in making connections between the abstract symbols of letters/words and concrete concepts within the reading process, it follows that mental imagery strategies can also serve to help students concretize abstract mathematical concepts in ways that facilitate more effective problem solving.

Table 1: Means, Adjusted Means and Standard Deviations for Images with Narrative Text

| Effect of Instruction | n | <u>M</u> | <u>SD</u> |
|-----------------------|----|-------------------|-----------|
| Posttest II | | | |
| SAM | 40 | 5.450 (5.398*) | 3.796 |
| visual imagery | 77 | 3.948 (4.042*) | 2.025 |
| comparison | 72 | 3.694 (3.600*) | 2.028 |

Adjusted means shown in parentheses. significant at the .05 level

Within the field of literacy instruction, effective teachers are cognizant of the importance of assisting students to step into the text world in order to actively construct meaning during the reading process (Langer, 1990). In the same fashion, students can also be taught to step into the world of mathematical problem solving. That is, the construction of mental images can actually serve as conceptual pegs upon which unfamiliar mathematical concepts can be hooked onto preexisting knowledge structures in ways that concretize abstract ideas. A specific instructional strategy that teachers can use to assist students to engage in mathematical mental imagery is through the construction of pictorial



Sensory Activation Model (Douville, 1998)

representations of mathematical concepts in illustrations and drawings. In order to pictorially represent an abstract concept, students must first construct the image internally before the image can be externalized in an illustration. The very acts of constructing mental images of abstract mathematical concepts and translating the corresponding images into illustrations not only concretizes the targeted concepts, but also provides for elaborative, Type II rehearsal of information that provides for deep level encoding and storage of the information (Craig & Lockhart, 1972).

More advanced mathematical imaging can be accomplished through storyboarding the steps of a problem or concept. In storyboarding activities, each step of a particular mathematical problem is pictorially represented in sequential order. In the following elementary level mathematical word problem, a sheet of paper folded three times to create 6 boxes or cells could be used to pictorially illustrate each step of the problem solution:

Jake went to the beach to collect shells. When he returned home, he had 15 beautiful shells. Jake decided to sort his shells by size. He put his 3 big shells in a blue box and his 6 medium shells in a red box. How many small shells did Jake have left to put in the yellow box?

- Cell #1: 15 shells are represented
- Cell #2: 3 large blue shells are represented
- Cell #3: 6 medium red shells are represented
- Cell #4: 3 large and 6 medium shells are represented together (addition)
- Cell #5: 15 shells are first represented, and the sum of the large and medium shells (9) are removed with a drawn diagonal line (subtraction)
- Cell #6: the 6 remaining yellow shells (solution)

Although the above example reflects simple addition and subtraction computations, more advanced mathematical concepts and computations can also be mathematically imaged through storyboarding.

In technologically rich societies, individuals are increasingly being robbed of the opportunity to construct personal images as media and computer programs create ready-made, digitized images at the touch of a button or keyboard. Unfortunately when our students have lost the ability to independently construct personal images, they have not only potentially lost the ability to engage in deep level conceptual processing, but also the ability to be creative, dynamic thinkers and problem solvers.

Therefore, mental imagery strategies designed to assist students in an active construction of knowledge represents a focus for continued investigations.

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