Chapter IV
Manipulating Multimedia Materials

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ABSTRACT

This chapter discusses a theoretical framework for designing multimedia in which manipulation, rather than perception, of objects plays the predominant role. The framework is based on research by cognitive psychologists and on Engelkamp's (1998) multimodal model of action-based learning. Although the assumptions of Engelkamp's model should be helpful for instructional design, they are not complete enough to include the additional demands of multimedia learning. These additional demands can result in unintended actions, involve sequences of related actions, and require reflection about domain-specific knowledge. Actions can be performed on either physical or virtual manipulatives, but virtual manipulatives exist in idealized environments, support continuous transformations of objects, and allow for dynamic linking to other objects, symbols, and data displays. The use of manipulatives in the Building Blocks and Animation Tutor projects provide illustrations.

INTRODUCTION

In his preface to *The Cambridge Handbook of Multimedia Learning* Mayer (2005) defines multimedia learning as learning from words (spoken or printed text) and pictures (illustrations, photos, maps, graphs, animation, or video). *The Cambridge Handbook* consists of 35 excellent chapters on many aspects of multimedia learning that emphasize the viewing of pictures. However, the word "manipulation" does not appear in the index. This does not imply that the manipulation of objects is ignored in the chapters but action receives comparatively little discussion compared to perception.

The purpose of this chapter is to provide a theoretical framework for designing multimedia in which manipulation, rather than perception, of objects plays the predominant role. The term "manipulation" in this chapter refers to the movement of an object by a person. The object is typically referred to as a "manipulative" in instruction and although the chapter focuses on virtual manipulatives that exist on a computer screen, it also includes research on physical manipulatives that exist in the environment. Examples include superimposing shapes to estimate relative areas and selecting and combining parts to build an object. Clicking on navigation buttons and changing parameters in simulations are not included as examples of manipulation.

The discussed theoretical framework for using manipulatives is based on research by cognitive psychologists that should be relevant to the design of multimedia instruction. It must be emphasized that the objectives of the laboratory tasks created by cognitive psychologists often differ from the objectives of the instructional software created by instructional designers. However, at this early stage in applying cognitive psychology to instructional design, I decided not to prejudge which findings will be most helpful and so include a variety of results that potentially could influence the effectiveness of manipulatives.

I use Engelkamp's multimodal model of learning to organize these findings and refer to recent research to illustrate assumptions of his model. I next discuss applications of the model to instruction by considering some differences between the free recall of action phrases that forms the empirical basis of his model and the instructional learning of schematic knowledge. Although instruction may use physical manipulatives, there are some advantages to using virtual manipulatives that I discuss in the next section. I conclude by summarizing two multimedia projects before proposing future directions.

BACKGROUND

There are few theoretical frameworks for understanding the role that object manipulation plays in instruction. In my article on cognitive architectures for multimedia learning (Reed, 2006) only one of the six theories incorporated action. Engelkamp's (1998) multimodal theory was designed to account for the recall of long lists of action phrases such as "saw wood", "play a flute", "blow out a candle", and "water a plant". The recall of action phrases is a very different task than the ones designed for multimedia learning but the central finding of this research is relevant. That finding – labeled the enactment effect – is that acting out phrases results in better recall than simply reading phrases (Engelkamp, 1998).

The multimodal components of Engelkamp's theory are illustrated in Figure 1. They consist of a nonverbal input (visual) and output (enactment) system and a verbal input (hearing, reading) and output (speaking, writing) system. All four of these modality-specific components are connected to a conceptual system. Engelkamp (1998) describes the many assumptions of his multimodal theory in his book *Memory for Actions*. I have listed the major assumptions (and page numbers) in Table 1 (See Appendix) and evaluate them below within the context of recent research on memory and reasoning.

1. Recall of observed actions should differ from that of performed actions because different systems are involved in encoding.

Engelkamp proposes that observations encode visual information about movement but performance encodes motor information, as is illustrated in Figure 1. One application of this idea to instruction is that observed actions can lead to performed actions such as initially observing an instructor's dance steps or tennis serve. Subsequent recall can then be influenced by both visual memories of observing the instructor and motor memories of performing the action.

One implication of this assumption is that a person should be better at recalling verb-action phrases by enacting them than by verbally encoding them or by observing another person