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Acquisition of procedures: The effects of example elaborations and active learning exercises

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Abstract

This study explored the effects of active learning and types of elaboration on procedure acquisition (writing database queries). Training materials emphasized elaborations of conditions for executing actions versus elaborations of the connection between conditions and actions. In the ''active'' conditions, participants performed structured exercises designed to encourage active processing. In the ''passive'' conditions, participants studied examples that contained instructional elaborations. Although excessive instructional information for more knowledgeable learners can hurt performance, our results indicate that condition–action elaborations improved procedural performance the most, in both the active and passive conditions. Active learning required longer training time but was offset by reduced test time.

Keywords: Instruction design; Procedure learning; SQL

A person's active involvement in the learning process appears to produce the most robust and flexible learning (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Renkl, 1999). *Active learning* is defined here as students producing self-explanations while engaging instructional material. The best instruction and training programs for knowledge acquisition should therefore be those that induce or enhance some type of active information processing on the part of the learner (Dufresne, Gerace, Hardiman, & Mestre, 1992).

Merrill, Reiser, Merrill, and Landes (1995; see also Merrill, Reiser, Ranney, & Trafton, 1992) found that students learned LISP programming more effectively with an intelligent LISP programming tutor than with more traditional instructional learning. They attributed this success to hints and explanations given by the tutor that enabled the learners to correct their errors and understand *why* their corrections were successful rather than leading learners to a solution by telling them the answer. Merrill et al. (1995) suggested that the computer-based hints and explanations were ''procedurally incomplete'', providing just enough explanation, but not too much, so that the participants were encouraged to articulate their reasoning and to focus on problem-solving processes.

Active learning enhances declarative (fact) acquisition because the learner generates connections among to-be-learned items or between a to-be-learned item and other related facts already known to the learner (Anderson, 1983; Reder, Charney, & Morgan, 1986). This produces the so-called *generation effect* (Jacoby, 1978)—better memory for self-generated items—that enables the learner to succeed in improving the probability of recall of these

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materials. One question is whether such effects apply to procedural learning. Learning a procedure is defined here as acquiring knowledge needed to construct the steps for solving a problem; it is not just learning facts about the domain, but also how to use them to construct a solution.

Renkl (1999) has argued that self-explanations (i.e., explanations *generated* by a learner) can be more effective than instructional explanations (i.e., explanations *given* to the learner) because the former type, if sufficient scaffolding is present, takes better advantage of the learner's prior knowledge, is better-timed, and can be more memorable (see also Atkinson, Derry, Renkl, & Wortham, 2000). Carroll and Kay (1985), while studying the effectiveness of prompts on people learning to use a word processor, found that giving participants exact procedures to be followed during training (a passive learning condition) did not improve long-term acquisition and transfer of word processing skills. On some transfer tasks, participants in the control group, who had to learn procedures with less guidance and therefore presumably acquired skills more actively, performed faster and with greater accuracy than the groups given the procedures more directly during training.

Chi and her colleagues (Chi et al., 1989; Chi & VanLehn, 1991) found that active learning correlated positively with level of later skill acquisition. In these studies, however, active learning was a dependent variable, obtained through talk-aloud protocols with weaker and stronger students; therefore, the connection between active learning and problem-solving performance was not demonstrated clearly given that the learners differed on a variety of dimensions such as prior academic performance.

One goal of the present study was to compare instructional elaborations (i.e., elaborations provided in the training materials) with self-generated elaborations guided by scaffolding (Renkl, 1999). The work outlined above suggests that instructional elaborations and self-generated elaborations have potential advantages and disadvantages in terms of training time and subsequent problem-solving time and accuracy.

1. What types of elaborations are best for procedural learning?

The observations and findings described above highlight the importance of active learning for fact and procedure acquisition. However, they do not identify which aspects of elaborations are the most effective for procedure acquisition. Several studies provide some guidance on this issue.

Protocol studies by Chi and her colleagues (Chi et al., 1989; Chi & VanLehn, 1991) and Pirolli and Bielaczyc (1989) have indicated that while learning, a student might try to self-explain actions presented in text and examples or errors generated during his or her own problem-solving attempts. Chi and her colleagues suggested that explaining is a mechanism of study that allows students to infer and explicate the conditions and consequences of each procedural item in the example as well as to apply the principles and definitions of concepts to justify them. That is, while studying examples, good students identify a context or situation in which a given action is appropriate and link relevant actions to that situation.

Pirolli and Bielaczyc (1989) also examined explanations generated by students while studying worked-out examples of LISP programming and created a classification of self-generated explanations. For present purposes, the two most relevant explanation classes concerned statements about the domain itself, LISP programming. Pirolli and Bielaczyc suggested that domain explanations can be divided into two types: (1) syntax-oriented explanations, referring to the syntax of program code and other surface features of the example; and (2) semantic explanations, involving an abstract interpretation of the process generated by a piece of the code.

The work cited above suggests that two types of elaborations are crucial for procedural learning. The first is the conditions under which a procedure or sub-procedure should be performed. This is important because learners often fail to understand *when* a procedure should be carried out. The second is the relationship between the goal and the necessary actions, that is, knowing *what* to do.

The second goal of the present study was to compare the effectiveness of the two types of elaborations described above. Initially, it might seem straightforward to provide (or lead learners to generate) elaborations on both conditions *and* actions in order to produce superior subsequent task performance. However, there are at least two reasons why this might not be the case. First, excessive information can produce too much cognitive load and interfere with schema development (Sweller, 1988; Sweller, van Merriënboer, & Paas, 1998), particularly if the additional information is not needed by that learner—the so-called "expertise reversal" effect (Kalyuga, Chandler, & Sweller, 1998). That is, sophisticated learners—which describes the learners in the present study—can actually suffer in their subsequent