

COMPONENTS OF COMPUTER SKILL ACQUISITION:
SOME RESERVATIONS ABOUT MENTAL MODELS AND DISCOVERY LEARNING

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SUMMARY

Current instructional strategies often place emphasis on the way in which a learner formulates a model of the task. In this context both "discovery learning" and "model-based instruction" have been emphasized. An empirical study is reported that suggests some limitations on these approaches in computer-based learning. Pure "discovery" in which the learner explores the computer system may not provide an adequate means for a person to evaluate his or her knowledge. Likewise, although it may be useful to provide models of the system in some cases, unless the user has some tools to help revise that model over time, the model instruction may actually interfere with performance. These results lend support to a somewhat more constrained "guided" form of discovery learning.

INTRODUCTION

Cognitive analyses of skill acquisition have suggested that "active learning" is an important component in learning to use computers (Carroll and Mack, 1984). This view has helped to foster a resurgence of the concept of learning by "exploring" the domain and "discovering" how things work (Brown, 1983). Likewise, the importance of the learner's mental structures have placed increasing emphasis on ways in which to help the user formulate an appropriate "mental model." As a consequence, instruction often attempts to provide model-based explanation of how some aspect of the computer works.

Although these concepts have been present in the literature on learning for some time, there is still relatively little evidence on the precise function of these techniques in computer skill acquisition. Although "discovery" learning has found continual support for a number of years (e.g. Craig, 1956; Egan & Greeno, 1973), we have found that subjects differ substantially with respect to their willingness and ability

to engage in exploratory tasks (Deck & Sebrechts, 1984). With respect to "mental models," several studies have examined the utility of giving users explicit functional models of the relevant processes. Although there have been a number of successful demonstrations of this approach in computing (eg. Mayer, 1981) as well as in other domains (e.g. Kieras and Bovair, 1984), there are questions about the precise role that such instructional information may have (e.g. Halasz & Moran, 1983; Reder, Charney, & Morgan, 1986; Sebrechts, Marsh, & Furstenberg, in press).

In combination, the data suggest that there may be limitations on the utility of discovery learning and explicit model strategies for instruction. This study tried to isolate the functions of "discovery" learning and explicit "model" explanations in the context of learning to use a computer operating system. First we compared an open-ended discovery learning context, in which subjects could explore the system in whatever way they chose, with more constrained problem solving, in which subjects were required to solve specific problems. Second, we examined how providing model information about the underlying system functionality would influence performance in the various learning conditions.

METHOD

Subjects and Design

Sixty-four subjects were trained on nine basic commands of the UNIX operating system: cd, pwd, ls, mkdir, rmdir, ln, cp, rm and mv. An equal number of subjects were randomly assigned to each combination of three training variables: (1) The type of instructional material was either (a) a "descriptive" version which specified each command's basic function and structure and provided a simple example or (b) a functional "model-based" version which added explanations about underlying system functionality and related these explanations to the examples for each command. (2) The instructional materials were either (a) present for reference during training on the system or (b) available only during instruction and absent during training on the system. (3) The training conditions consisted of three "problem solving" conditions in which subjects received a set of problems to complete and a "discovery learning" condition in which subjects were told that they could freely explore the commands they had learned on the system. The three problem solving groups consisted of (a) a group that received no feedback, the No Response (NR) group; (b) a group that received the correct answer whenever they finished typing in their answer to a problem, the Correct Answer (CA) group; and (c) a group that received system feedback in the form of error messages while working on the system, the Interactive Problem Solving (IPS) group.

Procedure

Subjects first read the appropriate instructional manual (descriptive or model-based) which provided the basic operating concepts and a brief explanation of each command. For half of the subjects, the instructional texts were removed after initial study. For the other half of the subjects, the text remained present during training, and subjects were able to refer to it whenever they wished. Initial instruction was followed by a training phase in which subjects interacted with the computer. The problem solving groups (NR, CA, and IPS) solved problems and received feedback according to their condition as described above. The discovery learning (DL) group interacted with the system as they wished without being required to solve any specific problems. In the evaluation phase, all subjects were given a new set of more complicated problems. In all cases, they interacted with the computer and received normal system feedback. However, they received no additional feedback and were not allowed to refer to any other materials.

RESULTS

Discovery Learning vs. Problem Solving

In general, Discovery Learning as defined here was a less effective strategy than Interactive Problem Solving. During training, the DL group showed a larger proportion of incorrect commands and less adequate exploration of the system than the IPS group. As a consequence, DL performance at test was not as good as that for the IPS group. Among the problem solving groups, there were also consistent differences: interactively solving problems on the system (IPS) was better than receiving the correct answer after each problem (CA) which was better than receiving no feedback (NR).

During the evaluation phase of the study, there was a similar pattern of results. Discovery Learning performance lagged behind that of Interactive Problem Solving. Within the problem solving groups, IPS was still the best although the Correct Answer group was almost as good. The No Response group continued to show the poorest performance.

Model-based Instruction: Training Phase

The type of instruction and the availability of the instructional material during learning also influenced performance. Their utility, however, depended on the specific learning context generated by the other variables. Thus, model-based instruction improved performance for subjects who had no other information available during

training. If subjects were allowed to refer to the materials during training in the absence of other feedback, however, model-based instruction lost its advantage. In fact, under these conditions, subjects who received model-based instruction took more time to solve problems than those who received simple descriptive instructions.

When subjects received the correct answer (CA), those subjects who had not received model-based instruction performed better. Presumably, the answer alone provided a simpler view of the system than the answer in combination with model information.

Finally, in the case of Interactive Problem Solving, model-based instruction was better for those subjects who could also access the instructions during training. For those who did not have the instructional material available, the simple descriptive version was better. (Since the DL group did not have specific target problems to solve during training, performance could not be directly compared with that for the three problem-solving groups.)

Model-based Instruction: Evaluation Phase

The effect of the two types of instruction during the evaluation phase was similar to that during the training phase. In addition, the Discovery Learning group showed a pattern of results similar to that of the Interactive Problem Solving group. Model-based instruction was useful when instructional materials were present; in the absence of those materials, descriptive instruction was better.

In sum, a model appeared to be useful in two conditions, either when there was no other available information (NR and no reference to instructions) or when there was maximal information (DL or IPS with reference to instructions). In the intermediate conditions when only some system information was available, the model was of little use or actually interfered with performance.

DISCUSSION

Discovery Learning

The results in this study suggest two limitations on commonly held beliefs about instruction. First, although there are many presumed advantages to learning by discovery or exploration, the data presented here suggest boundaries on that generalization. Without substantial prior knowledge, a user may not know what constitutes appropriate exploration (cf. Carroll et. al, 1985). In the absence of specific problems, learners may not be able to determine the adequacy of what they have learned. This restriction on discovery as a learning strategy extends other notions

about the limitations of active learning (Deck & Sebrechts, 1984), restrictions on the utility of interactive learning (Sebrechts & Deck, 1986) and limitations in using unstructured discovery based environments, such as LOGO. These results do not, of course, argue against discovery learning in general. Instead they suggest that we need to focus on how such discovery can be guided to produce optimal learning. Initial results concerning such "guided" discovery are promising (Carroll et al., 1985).

Model-based Instruction

Second, although our data support the utility of developing mental representations, there are strong constraints on the effectiveness of explicit models in that development. In the absence of other information, providing a functional model during instruction can substantially enhance a user's initial conception of the domain. In general, however, such initial formulations tend to be flawed and require continual modification and adaptation. If the appropriate reference materials and interactive tools are available to evaluate changing conceptions, this form of learning can be very useful. Thus, for example, those subjects who received the model-based instruction may have found conflicts with their models as they were solving problems. Such conflicts could be resolved as long as it was possible to try out solutions on the system and to refer back to the instructions. When subjects did not have the system feedback and instructional materials available, however, they may have been unable to resolve confusions in their emerging models. As a consequence, the model-based instruction could actually impede learning under certain circumstances. In the absence of the appropriate resources to understand and resolve conflicts, a more restricted set of instructions, such as that proposed by the "minimal manual" (Carroll & Carrithers, 1984) may produce better learning.

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