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ABSTRACT

This research explored the thesis that mental model construction can be an effective instructional strategy for mental models learning by constructing a prototype that embodies this approach. The mental model to be learned was the Internet, including the components of the Internet, their functions, and their relationships to one another. To do this, students were required to place the components of the Internet in their proper places and assemble the proper functions of each component. The model-assembly module was constructed as a computer-based training module, using Authorware authoring software. A group of 43 community college students in an "Introduction to Computers" course participated in a pilot test. Both the control group and the treatment group went through an instructional activity and a reassembly activity. In the instructional activity, the control group observed the model assemble itself, while the treatment group were required to drag each component to its correct location. Scores on a posttest and the reassembly activity were compared. Results indicate a better grasp of the model within the treatment group, as well as significant differences between age groups and between males and females. (MES)

Student Model Construction: An Interactive Strategy for Mental Models Learning

By:

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STUDENT MODEL CONSTRUCTION : AN INTERACTIVE STRATEGY FOR MENTAL MODELS LEARNING

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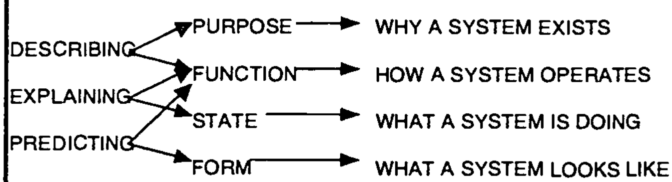
Introduction

A " mental model" is a knowledge structure, composed of concepts and the relations between them (Jonassen, Beissner & Yacci, 1993; Shavelson, 1974). A mental model is a systemic type of learning outcome - it is a system of information, concepts, and relationships between them. When people have a mental model of a system, be it a judicial system or a washing machine, they know its components and how the components affect one another.

A mental model is a learning outcome distinct from declarative and procedural knowledge (Jonassen & Tessmer, 1996), going beyond semantic relationships and skills acquisition to systemic understanding. Building on the theory base that information in memory is encoded in and retrieved from a structure that preserves meaning, theorists posit mental models as powerful engines for higher order cognitive processes. If learners have a mental model of a device or system, the model enables them to solve problems, generate inferences, and make predictions about the system that is modeled (Johnson-Laird, 1983; Wilson & Rutherford, 1989). Figure 1 models some of those functions.

Figure 1. Purpose of Mental Models.



(Rouse & Morris, 1986, p. 349)

Rouse and Morris' work with troubleshooting and mental models would suggest another function of mental models learning: predicting what is wrong with a system (diagnosing).

There are at least three important implications of mental model research that should be considered by instructional designers. First, learners form mental models, whether the designer takes that fact into account or not, and inaccurate models can impede learning (Carroll & Thomas, 1982; Rouse & Morris, 1986; Norman, 1983). Second, troubleshooting performance (a type of problem solving) can be facilitated through construction of mental models (Gentner & Gentner, 1983; Rouse & Morris, 1986; Lesgold, 1986; Mayer, 1989; Rodgers, Rutherford, & Bibby, 1992; Downey, 1996). Structured knowledge has been found to be a powerful predictor of the ability to apply content knowledge to solve problems (Gomez, Hadfield, & Housner, 1996; Cormier & Hagman, 1987).

Finally, research on expert knowledge representation indicates that structural knowledge is essential to expert performance (Chi & Glaser, 1984; Larkin, McDermott, Simon, & Simon, 1980). Tardieu, Erlich, & Gyselinck, (1992), for example, found no difference between expert and novices at the propositional level of memory, but significant differences at the mental model level. That is, there was little difference in the amount of domain knowledge that each group possessed, but there were differences in the way that knowledge was organized. Although the expert must have a sufficient knowledge base to draw upon, if it is not expertly structured, it is of little advantage.

Mental Models Instructional Strategies

For years, Richard Mayer (1984,1997) has explored methods for teaching students a mental model of a simple system such as a brake system, pump, or weather system. In general, his research has indicated that graphic-textual representations of mental models are more effective than textual descriptions (Mayer & Sims, 1994), and that animated graphical representations are more effective than static ones (Mayer, 1997). His measures of mental model performance are transfer of learning, inference and problem solving.

Mayer's instructional methods, as well as that of other researchers such as Kieras and Gentner, focus upon learners as observers of a model, not as constructors of it. At most, learners may manipulate variables in the model to observe the effects of their interaction (e.g., increasing the resistance in a circuit model to observe the effects on the system).

Consequent with the learning theories of constructivism (Savery & Duffy, 1996) and constructionism (Kafai, 1997), we believe that mental models may best be learned when the learner has an opportunity to build the model, not just observe it. Research into computer-based learning indicates that learners understand and retain information better when they interact with it in ways that encourage elaboration, inference, or other forms of meaningful learning (Hannafin & Peck, 1987). In other words, building a model may be more effective than studying a model, whether static or animated.

The theoretical assumption behind this model building strategy is that:

> Someone who acquires a mental model of a system acquires an understanding of the components of a system and their relation to one another. This includes an understanding of the function of the component and its effect on other components.
>
> From a constructivist and constructionist perspective, a learner can best acquire this mental model by personally constructing the model - by connecting the concrete components and their abstract relations
>
> The model construction task must be scaffolded by access to cues and information, but must not show the model itself. The most effective learning strategy involves students inferring the place and function of system components. This building task forces students to reflect on the function of the component and its effect (relationship) on neighboring components.
>
> Mental model learning acquisition is best measured by three related measures: troubleshooting diagnosis, troubleshooting solution, and prediction of change of state. All three measures can be used for abstract systems (e.g. judicial system) as well as concrete ones (pump, carburetor).

Prototype of the Instructional Strategy

To explore the thesis that mental model construction can be an effective instructional strategy for mental models learning, we constructed a prototype that embodies this approach. The mental model to be learned is the Internet, meaning the student should learn the components of the Internet, their functions, and their relationships to one another. To do this students must learn to place the components of the Internet in their proper places, and assemble the proper functions of each component. For example, students should learn the function of a modem, how it depends on its preceding component (the computer) for a signal, and how it transmits the modem signal to the next component (the telephone). This model-assembly module was constructed as a CBT module, using Authorware authoring software. Learners must build the model from its disassembled parts, and must assemble the functions of the parts as well (Figure 1). The module contains instructions on how to use the system, the model itself, and test for acquisition of the mental model. We then tested the module with a group of learners.

Prototype Test

Subjects

A group of 43 subjects participated in a pilot test in November 1999. All subjects were students in the first author's undergraduate *Introduction to Computers* evening course in a community college in southeastern Texas. The pilot test was held during week 13 of a 17-week course.

Method

All students were informed at the beginning of class that the instruction for that session would be delivered by a computer animation. They were also advised that the instructor wished to collect anonymous data on their interaction with the computer animation as a pilot test for his dissertation project. They were further advised that their participation in the data collection was strictly voluntary, and that if they did not wish to participate in data collection they could exercise that option by not inserting the data disk into their computer prior to starting the instruction. All students elected to participate in the anonymous data collection.

Materials

Materials for the pilot test consisted of

1. the model-assembly module, which had been copied to the hard drive of each computer prior to the start of class;
2. a diskette containing a folder for the model-assembly module to write data into;
3. a brief paper-and-pencil background survey (age, sex, do you use a computer at home or work, do you use the Internet at home or work) ; and
3. a brief quiz with items requiring the student to infer causes of malfunctions, identify system components, and infer system functions.

Procedure

Students were instructed to double-click the icon for the model-assembly module to open it, and to go no further until the instructor had confirmed that all had been opened successfully. At this point a random number generator in the Authorware module had assigned each subject to either the control group or the treatment group;

thus, assignment to groups was double-blind. When the instructor confirmed that all modules had opened properly, the students were told to proceed in accordance with the instructions they saw on their screens.

Both the control group and the treatment group went through two computer-based activities: an instructional activity and a reassembly activity. In the instructional activity the control group observed the model assemble itself by clicking on a Continue button as each component of the model was explained. Clicking caused the component to go to its assigned place and the next element of instruction to appear. The treatment group saw identical components and instruction, but were required to drag each component to its correct location; if they dragged to the wrong location, the component snapped back to its start position, and the target spot was highlighted to facilitate a second try.

In the reassembly activity both groups saw identical screens. The components were scattered around the edge of the screen, and the students were instructed to drag each component to its correct location; the locations were consecutively numbered to indicate both location and sequence. As each component was "dropped," the software wrote to the diskette file the component name, the time, and whether the attempt was right or wrong. When all 19 components had been correctly placed, the module moved automatically to the final screen, which advised the student to click on File, Quit to end the program and await further instruction. Data written to the diskette file were: elapsed time in the reassembly event, number of correct tries, number of incorrect tries, and the date and time.

Students were then given the paper-and-pencil instruments and asked to read the file number from their diskettes (the random number generated at the outset), write that number on the first page of the questions, and answer the questions.

Results

The reassembly task was a recall test, requiring the student to remember the basic location of the components. The quiz consisted of 7 items requiring the student to infer causes of malfunctions, identify system components, and infer system functions. The scores on the paper-and-pencil instrument and the number of wrong placements in the reassembly activity were compared using a pooled t-test and an ANOVA in Data Desk. Both tests produced identical results:

		Control	Treatment
Drag and drop errors	n	25	18
$p=0.79$	M	23.68	22.17
	SD	17.42	14.87
Quiz correct	n	23	16
$p=0.59$	M	5.0	5.25
	SD	1.45	1.34

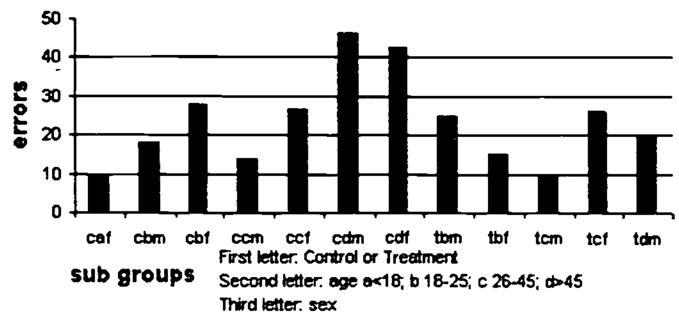
The most significant data from this pilot study was the instructor's observation of several students during the reassembly activity repeatedly dragging a component to the same wrong spot. The students apparently did not understand that the failure of the component to snap into place indicated it was being dragged to the wrong location. The expressions on their faces clearly showed frustration (as opposed to indifference or vagabonding). Response to this phenomenon is discussed below under Conclusion and Future Plans.

The students self reported the following in the Background Survey:

Age <18: 1, 18-25: 17, 26-45: 15, >45: 6
Sex f:17, m: 23
Use computer at home – yes: 34, no: 5
Use Internet at home or work – yes: 25 no:14
(n from the paper-and-pencil instruments is lower than 43 because of failure to complete portions of the instrument and 1 case of a student misreporting the random number from the diskette.)

The chart below illustrates an interesting result in scores on errors in placement of components. The over 45 age segment of the control group had clearly higher error totals than any other group. This part of the results

Figure 2. Summary of Drag and Drop Errors



was not tested for statistical significance; however, in the Background Survey 5 of 6 responded yes on using a computer at home or office, and 3 of 6 responded yes on using the Internet at home or office.

Conclusions and Future Plans

The data suggest some better grasp of the model within the treatment group, although the observed errors in the drag-and-drop tasks likely account for several high error scores in both groups in the reassembly task. This failure to understand the nature of the drag-and-drop tasks must be addressed as the first priority. To this end an additional activity has been placed between the instruction activity and the reassembly activity to demonstrate how to drag-and-drop and to emphasize that the movement of a component back to its start position means that it was dropped at the wrong location.

The data show apparently significant differences between age groups and between males and females within age groups. These results suggest the desirability of using age and sex as covariates in future studies.

This pilot study did not attempt to assess structural knowledge. Future studies will include structural knowledge comparisons between novices and experts using Pathfinder techniques.

The Background Survey, Comprehension Test, and Pathfinder data collections will all be put into the Authorware module so that data collection will be further streamlined and the data itself will be entirely contained on a single diskette. Having all the data written directly to disk as it is generated will eliminate logistical distractions from the experiment and will facilitate conducting the experiment.

The participants in the pilot study generally indicated satisfaction with the instructional material in post-experiment, informal conversations. They were intrigued by the Authorware product and were eager to learn more about the Internet. Their attitude suggests a positive level of receptivity to both the computer-based method and the reassembly activity within it. This augurs well for further studies.

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