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ABSTRACT

This study is an investigation of how modeling aids learners in developing problem solving skills within a computer learning environment. The task given to the 45 undergraduate and continuing education students serving as subjects, was to solve a crime in the computer game, "Where in Time is Carmen San Diego." Three subject groups received one of the following treatments: Expert Model, Novice Model, or No Model. Modeling entailed subjects viewing a computer-based animated and narrated movie showing how either an expert or novice completed the task. Results of the study indicate that modeling does not have an effect on the performance of participants, however it did contribute to the development of cognitive skills. (Contains 27 references.) (Author)

Title:

The Effects of Modeling to Aid Problem Solving in Computer-Based Learning Environments

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Abstract

This study is an investigation of how modeling aids learners in developing problem solving skills within a computer learning environment. The task given to 45 subjects was to solve a crime in the computer game, Where In Time Is Carmen San Diego. Three subject groups received one of the following treatments: Expert Model, Novice Model, or No Model. Modeling entailed subjects viewing a computer-based animated and narrated movie showing how either an expert or novice completed the task. Results of the study indicate that modeling does not have an effect on the performance of participants, however it did contribute to the development of cognitive skills.

The Effects of Modeling to Aid Problem Solving in Computer-Based Learning Environments

The capabilities offered by computer-based learning (CBL) systems have led to significant innovations in instructional delivery systems, specifically in the design of simulations, demonstrations and drill-and-practice. The design of many CBL programs is linear and systematic. However, new paradigms for implementing CBL, such as hypermedia, require new design models and prescriptions to guide the development of instructional systems.

This study focuses on the instructional method of modeling and its application in a CBL environment. It is imperative that the importance of modeling is not misunderstood. We believe that there is a need for a more effective way to facilitate cognitive learning in a CBL environment, and that modeling delivered by computer is a strategy with considerable potential. Specifically, we want to determine how computer-based modeling of strategies within a CBL environment influences the acquisition of cognitive skills.

Theoretical Background

The history of modeling includes such theorists as Miller & Dollard, Bandura, and even Aristotle. Their work focused mainly on the concepts of imitation and observational learning. Aristotle noted that an individual, "Is the most imitative of living creatures, and through imitation learns his earliest lessons; and no less universal is the pleasure felt in things imitated." (Butcher, 1922, p. 15) More recently, the social learning theorists Miller and Dollard (1941) offer a cogent description of the role of imitation and social learning, emphasizing that imitative learning is an acquired social behavior. Bandura (1971) conducted extensive research on psychological modeling in the behaviorist realm.

A comparison of definitions of modeling is useful for isolating attributes of this instructional treatment. Bandura (1971) describes modeling using a broad range of terms, "Among the diverse terms applied to matching behavior are 'imitation', 'modeling', 'observational learning', 'identification', 'internalization', 'introjection', 'incorporation', 'copying', 'social facilitation', 'contagion', 'and 'role taking'" (p. 3). Romiszowski (1981), on the other hand, gives an apt description of modeling as the showing, not telling, a learner some set of processes, steps, skills and strategies to solve a task. Davies (1981) and Gagné (1987) define modeling simply as "demonstrations."

More recently, Welsh (1992) differentiates two types of modeling, behavioral modeling and cognitive modeling. We've attributed behavioral modeling to much of the research we've illustrated in the preceding paragraphs. Cognitive modeling, on the other hand, incorporates systematic verbalization on the part of the model to make his or her thinking processes visible to others. Thinking aloud and mental modeling are two strategies that describe what occurs during cognitive modeling.

Behavioral Modeling Research

"Algorithms guarantee solutions: if properly carried out they always yield the correct answer." (Perkins, 1986:198). Demonstrative modeling is, in essence, an algorithm, since it is the objective of the modeler to show the learner the perfect solution to the problem. The research has consistently shown that demonstrative modeling strategies for completing tasks have yielded greater performance than no modeling (Yaeshima, Ninomiya, Ohnogi & Oda, 1982; LaNunziata, Cooper & Hill, 1985; Rivera & Smith, 1987; Baggett, 1987; Smith & Hailey, 1988; Robert & Chaperon, 1989).

Smith & Hailey (1988) found that demonstrative modeling techniques resulted in better performance in learning breast self-examination over narrative explanation and written instructions. In their experiment, the experimenters assigned 60 college women to one of three instructional treatments: actual breast demonstration, synthetic breast demonstration, and no demonstration. After one month, the two subject groups who received the demonstration treatments performed better than the control group. Yet after three months, all differences between experiment and control subjects disappeared.

Baggett (1987) investigated the use of a narrated film and a correctly assembled object as stimulus in the task of assembling a toy helicopter from a number of given pieces. The modeling by film consisted of a 15 minute, narrated 8mm film showing an expert naming and putting together the pieces to assemble the helicopter correctly. The assembled object was a completely assembled toy helicopter. Baggett found that any combination of film and the assembled helicopter resulted in greater task completion than either treatment in isolation.

Robert and Chaperon (1988) conducted a linking experiment between behavioral and cognitive modeling. In their experiment, they used a Piagetian horizontal representation water-level task with college women. Experimenters randomly assigned women to one of three groups: cognitive modeling, exemplary modeling and no modeling. Cognitive modeling entailed watching a videotape of a woman as she correctly solved three water-level tasks. During her solution, she both demonstrated and verbalized her actions. Exemplary modeling used the same videotape of the woman performing the task, however she never voiced any part of her solution. The no modeling group received no modeling of the task. Experimenters immediately evaluated subjects after treatment on their ability to solve a similar task with the same water bottles and a task with different water bottles. Fifteen days later, experimenters conducted a delayed post-test to measure stability of the learned behavior.

The results from this experiment clearly showed the impact of both cognitive modeling and exemplary modeling in enabling women to master the water-level task. However, the cognitive modeling component appeared to be the critical component that fostered improvement in the learner.

Cognitive Modeling Research

There is still the question we raised earlier of the technique one uses to model cognitive processes--i.e., think-aloud or mental modeling. Schoenfeld (1985) uses think-aloud routines to model the cognitive process of solving math problems. He has an ongoing contest whereby students present math problems for him to solve. In solving the problem, he thinks out loud, articulating his strategies for solving the problem. In essence, he is showing the students how he thinks in seeking a solution to a math problem, exposing them to all the complexities, mistakes and pitfalls one must deal with along the way.

In teaching reading skills to biology students, Mikulecky, Clark and Adams (1989) evaluated modeling as a means of coaching college freshmen to read texts more strategically. In particularly, they used computer-based presentations of text and analysis to model strategies such as identifying key concepts, writing linking summary statements to compare and contrast key concepts, and graphically mapping relationships among key concepts. They found that modeling these reading skills for biology students with a CBL program yielded higher exam scores over a control group that did not receive the CBL lessons.

Mandinach (1987) compared discovery learning and participant modeling as a method to develop strategic planning knowledge. Two groups of seventh and eighth grade students played a game called Wumpus. The experimenters used a discovery learning paradigm for one group, while the other group received participant modeling that systematically modeled appropriate cognitive skills and strategies. Students in the participant modeling group performed better in task completion; however the discovery learning group performed better in the transfer of skills to other tasks.

Synthesis

Between both behavioral modeling and cognitive modeling, the key instructional elements that comprise models are demonstration and verbalization. While demonstration is an established construct, verbalization is somewhat more undefined. For example, in Robert and Chaperon's (1988) research, verbalization was operationalized by describing one's actions during a perfectly demonstrated task. On the other hand, Schoenfeld (1985) also verbalizes his solution to math problems, however this verbalization includes the mistakes he is making and how he resolves those mistakes. We believe the demonstration of mistakes and verbalization of how to recover from them is a more effective instructional strategy for facilitating the development of cognitive skills than modeling perfect solutions. Thus, our research will investigate the differences between these two verbalization strategies in the context of cognitive modeling within CBL.

Hypotheses

On the basis of the literature, we expect our study to replicate the findings of prior modeling research.

H1: Participants who are shown a model of how to perform a task will perform better on that task than participants who are not shown a model.

How we define the protocol for modeling of cognitive processes is important to developing our study. Our primary concern is how experts think about solving tasks, and how to teach those thinking skills to others.

In the context of prior modeling research, we've developed two constructs for modeling. The first construct is the expert demonstration model, whereby an expert demonstrates and explains how to perform a task perfectly. The second construct operationalizes one of the salient features of Schoenfeld's research, namely the modeling of how to deal with errors. In this construct, a novice performs a task while an expert provides commentary on the novice's performance.

The showing of incorrect solutions is an important distinction to make between expert and novice modeling. Expert modeling, as described in the literature, tends to show the correct performance of a task, whereas novice modeling shows both correct and incorrect (with recovery) solutions. People make mistakes every day, and learning how to recover from those mistakes is an important skill. We believe the observation of a novice's recovery from incorrect solutions contributes greatly to acquiring cognitive skills. Therefore, we predict that novice modeling will result in successful completion of a task over the expert model since the participant will learn how to avoid and recover from common mistakes novices tend to make.

> H2: Participants who observe a novice model while listening to an expert comment on the novice's performance will perform better in a task than participants observing an expert model.

Performance is not the only measure of success. Our interest in the cognitive skills a learner acquires as a result of instruction drives our belief that modeling will have a positive effect on the key strategies a participant uses in solving a task.

H3: Participants who observe a model will use key task strategies more effectively than participants who do not observe a model.

H4: Participants who observe the novice model will use key task strategies more effectively than participants who observe the expert model.

Another measure of a learner's cognitive skill is articulation. Collins, Brown & Newman (1988) suggest that having a learner articulate what they know, by explaining how they plan to solve a problem or why they applied a particular solution, one can get a sense of the cognitive skills they've learned. Thus, we will investigate how the different modeling treatments affect the participant's articulations.

H5: Participants who observe a model will have stronger articulations about how to solve a task than participants who do not observe a model.

H6: Participants who observe the novice model will have stronger articulations about how to solve a task than participants who observe the expert model.

H7: Participants who have strong articulations will use key task strategies more effectively than participants who have weak articulations.

H8: Participants with strong articulations about how to solve a task will perform better in a task than participants with weak articulations.

Method

Design

The experiment was a 1-by-3 design. There was one variable, modeling, with three levels. The levels were expert, novice, and control. The expert level consisted of a modeling presentation showing an expert playing Where In Time

Is Carmen San Diego (WITICSD) with the expert's vocal narration. The novice level consisted of a modeling presentation showing a novice playing WITICSD with an expert's vocal analysis of the novice's performance. The control level consisted of no modeling presentation.

Participants

Fifty-two undergraduate and continuing education students from an introductory computer course at a large midwestern university signed up to participate in the study. The course instructor awarded extra credit to the participants for participation. We screened participants for prior experience with WITICSD. None of the participants had ever played WITICSD or any of the other Carmen San Diego games. Seven participants failed to show up for their appointment, resulting in 45 participants who contributed data to the study.

Materials

Materials for the study included a Macintosh® SE computer, WITICSD software and documentation, Microsoft Word™ software, custom-designed modeling presentation software, written instructions, a pad of paper, and a pen.

WITICSD is an educational software game. In the game, the player takes on the role of a detective solving a crime. Solving the crime entails interacting with the software to obtain clues, tracking the criminal through time and space, acquiring an arrest warrant, and arresting the criminal. Players decipher clues about the identity of the criminal and the destination he or she is traveling to by using the New American Desktop Encyclopedia, which comes with the software. We also provided the standard documentation for WITICSD, which includes the encyclopedia, instructions on how to use the software and hints for playing the game.

In order for participants to write their articulations, we used Microsoft Word software for word processing. Thus, participants wrote their articulations using the computer.

The custom-designed modeling presentation software consisted of MediaTracks™-produced "movies." MediaTracks enables one to record actions seen on the computer screen. After one records the movie, one can edit and add sound to the movie. The result is an animated, narrated presentation. We produced one movie for presenting the study's instructions to the participant, one movie for the expert treatment, and one movie for the novice treatment.

The instruction movie was 3:17 (minutes:seconds) in length. The content of the movie entailed screens of text that illustrated the narration of instructions for the study (see Appendix A). We also provided a print version of the instructions to the participants.

The expert movie was 7:16 in length. The content of the movie entailed an expert playing WITICSD, showing the perfect solution for playing the game. The expert's narration consisted of noting the strategies and heuristics he used while playing the game (see Appendix B).

The novice movie was 10:54 in length. On the basis of observations of novices playing WITICSD, we identified the most common mistakes novices make. The content of the movie was a novice playing WITICSD. An expert narrated as the novice performed. The narrator noted the successful and unsuccessful strategies the novice was using (see Appendix C).

It is important that we make clear the distinction between the expert and novice movies. The expert movie emphasized a perfect path solution to the task and illustrated advanced techniques for solving the problem whereas the novice movie illustrated errors and their outcomes and solutions in the course of playing the game.

Additional materials for the study included a blank pad of legal paper and a pen.

Procedure

Pre-Treatment Activities. Participants signed up for individual, one hour time slots over a one month period in the late fall. To confirm their appointments, we contacted each participant by phone or E-mail. We told participants that they would be user-testing some educational software.

We conducted the study in the conference room of a university building. The computer was on the conference room table. The blank legal pad and the pen were to the left of the computer, and the instructions, program documentation and encyclopedia were to the right of the computer. The experimenter sat to the back and right of the participant in order to observe all of the participant's actions.

When the participant arrived at the testing site, the experimenter explained the nature of the experiment to the participant as well as issues of confidentiality and voluntary participation. In order to decrease anxiety, the performance of the software, not the participant, was emphasized. The experimenter told participants that they would be testing some educational software and that our interest was in the software's performance, not theirs.

Next, the experimenter pointed out the resources the participant had at his or her disposal throughout the study. The experimenter showed the participant the documentation, instructions, encyclopedia, notepad and pen.

The experimenter then played the instruction movie for the participant. Prior to playing the movie, the experimenter reminded participants that they had a printed copy of the written instructions that they could use at any time during the experiment or to follow along during the movie.

Since the focus of this study was on problem solving strategies and not procedural knowledge of using the software and hardware, we wanted to make sure all participants were comfortable in the procedural aspects of the Macintosh and WITICSD before receiving treatment. After the participant had viewed the instruction movie, the experimenter would explain the basic use of the computer and the mouse pointing device. This required that the participant demonstrated proficiency in using the mouse to interact with the computer. We always observed accomplishment of this exercise.

In order to make the participant familiar with WITICSD user interface, the experimenter conducted a practice task. In this task, the experimenter guided the participant in using the WITICSD software by exploring one location. The experimenter explained how to click the various buttons, obtain clues, and travel from one location to another while the participant clicked the appropriate buttons. The experimenter told the participant that this was a practice task for their familiarity only and he encouraged them not to be concerned about solving the task successfully. Participants could ask questions about the functional use of the software and hardware only during this practice task.

These orienting activities and associated practice not only helped the participants learn about how to use the software, but helped form the context for the task itself, especially the modeling.

Treatments. The experimenter randomly assigned participants to one of the three treatments, expert, novice and control. For the expert and novice treatments, the experimenter prefaced the showing of the appropriate movie with the statement that the participant will now see a short movie that will give the participant more information about playing WITICSD. The experimenter encouraged the participant to do nothing else but watch the movie. The control treatment group did not watch any movie.

Articulation Task. Upon completion of the treatment, the experimenter opened the word processing software and instructed the participant to answer the question, "Explain to a friend how to play Where In Time Is Carmen San Diego." Each participant had five minutes to answer the question. When the participant finished his or her answer, the experimenter saved the answer in a file named after the participant.

Game Task. At this point, the participant played a single game of WITICSD. The experimenter set up the software so that all participants played the same game, the stolen Sultan's Howdah. In order to avoid participants who, lacking motivation to work efficiently, simply randomly pressed buttons to finish the experiment quickly, we offered a $10.00 prize to the participant who completed the game with the most remaining chronotime (a measure of efficiency used in the game).

Dependent Measures. During the task, the experimenter recorded data using a data tabulation instrument (See Appendix D). The experimenter recorded data for each location the participant visited.

- Location/Date. The location and date the participant navigated to while playing WITICSD. For example, France, 1892.
- WITICSD Chronotime. The chronotime displayed on the game screen was recorded when the participant first entered a new location. When the participant made a successful arrest, the ending chronotime was also recorded. Unsuccessful arrests resulted in a chronotime of 0 being recorded.
- Actual chronological time. Time was recorded to the second at the beginning and conclusion at each location and for the entire game.
- Witness. One point (or hash mark) was recorded each time the participant went to the witness for clues. If the participant had the

option to obtain more information while viewing the witness, an additional mark of "m" indicated that the participant viewed that "more" information, and a mark of "o" indicated that the participant did not view more information. If no "more" option was available, a dash (-) was recorded beside the hash mark in the witness box.

- Informant. One point was recorded each time the participant went to the informant for clues. If the participant had the option to obtain more information while viewing the informant, an additional mark of "m" indicated that the participant viewed more information, and a mark of "o" indicated that the participant did not view more information. If no "more" option was available, a dash (-) was recorded beside the hash mark in the informant box.
- Scanner. One point was recorded each time the participant went to the scanner for clues. An option to scan further was come across randomly after an initial scan was completed. An "f" was recorded beside the scan hash mark if the scan further option was taken.
- Note Taking. One point was recorded each time the participant wrote a note. For example, if the participant wrote a note, the performed another recordable activity, such as using the encyclopedia, then wrote another note, two points would be recorded. On the other hand, if the participant wrote a note, thought for a while, then wrote another note, only one point would be recorded since the participant did not perform a recordable activity between note writing.
- Reference. One point was recorded each time the participant used the New American Desktop Encyclopedia to look up information. For example, if the participant used the encyclopedia, then performed another recordable activity, such as taking a note, then referred back to

the encyclopedia, two points would be recorded for this measure. On the other hand, if the participant used the encyclopedia, thought for a while, then used the encyclopedia again, only one point would be recorded since the participant did not perform a recordable activity between the two instances of using the encyclopedia.

- Program Documentation. One point was recorded each time the participant used the program documentation to look up information. For example, if the participant used the program documentation, then performed another recordable activity, such as taking a note, then referred back to the program documentation, two points would be recordedfor this measure. On the other hand, if the participant used the program documentation, thought for a while, then used the program documentation again, only one point would be recorded since the participant did not perform a recordable activity between the two instances of using the program documentation.
- Select Clues. One point was recorded for each plain clue, such as sex, eye or hair color, the participant entered into the crime computer database.
- Subtle Clues. One point was recorded for each subtle clue, such as the criminal's favorite author or artist, the participant entered into the crime computer database. Randomly, the game would present hair or eye colors which required some inferential problem solving skill. For example, "she had hair the color of mahogany" is an inferred hair color clue. When such a clue was correctly recorded in the cri ie computer database, one point was recorded in the inferred clue box.

- Arrest Warrant Attempt. One point was recorded each time the participant attempted to get an arrest warrant by clicking the Compute button in the crime computer database.
- Arrest Warrant. One point was recorded when the participant obtained an arrest warrant.
- Task Complete. One point was recorded when the participant completed the task by arresting the suspected thief. This means that if the participant falsely arrested a thief, the task was recorded as complete even though it was not successfully completed.
- False Arrest. One point was recorded if the participant falsely arrested a suspect, by either not having an arrest warrant or having an arrest warrant for the wrong criminal.
- False Leads. One point was recorded if the participant followed the suspect to an incorrect destination.

Success in completing the task, which we call outcome, was operationalized in the following manner. We scored participants who acquired the correct arrest warrant, successfully tracked the thief, and made the arrest as 3. Participants who acquired the correct arrest warrant **or** tracked the thief and made the arrest were 2. Participants who **neither** obtained the correct arrest warrant nor tracked the thief and made the arrest were 1.

We determined the effectiveness in completing the task by scoring and combining the four key task strategies, witness, informant, scanner, and notes, into one measure, called effectiveness. We judged a participant to be effective in their use of key strategies if they don't use the witness and informant more than once for each location, don't use the scanner at all, and take at least one note at each location.

Scoring each of these strategies was in the following manner. If the participant accessed the witness clue one or fewer times per location, we awarded one point. Accessing the witness clue two or more times resulted in no points. We totaled the points, then divided by the total number of locations visited by the participant, resulting in a score between 0 and 1. We used the same methodology to calculate the score for the informant. Scoring for the scanner was similar to the witness and informant, however not using the scanner resulted in one point per location, while using the scanner at a location resulted in no points. Scoring notes was also similar to the witness and scanner, with one point awarded per location if there was at least one note, and no points awarded if there were no notes. We calculated a mean score for the effectiveness of the key strategies by adding the scores for witness, informant, scanner, and notes, then dividing by four.

Two raters judged the articulations. They classified the articulations into four equal sets of bad, good, better and best articulations. We then combined these articulations into two equal sets, with the bad and good sets classified as weak articulations, and the better and best sets as strong articulations This rating resulted in an inter-rater reliability of .75. Differences were discussed and resolved by the two raters.

Debrief. At the conclusion of the experiment, the experimenter explained to the participant the actual purpose of the study. In addition, the experimenter was able to ask the participant several informal qualitative questions about his or her performance. We wrote the responses to these questions on the participant's data sheet. Participants were also able to ask the experimenter questions about the study. We concluded the study by thanking the participant for their help and assuring them they would receive extra credit for their class.

Results and Discussion

Hypotheses One and Two

Our first hypothesis predicted that both the novice and expert modeling would result in better task performance than the control. We determined task performance through two measures, outcome and chronotime. Participants who obtained an arrest warrant and tracked the thief successfully received credit the remaining chronotime WITICSD. This number ranged from 1 to 21, whereby the higher the number, the more successful we judged the participant. All other participants received 0 chronotime illustrating their failure in successfully completing the game.

We used a one-factor ANOVA to analyze these variables. There was no significant difference between the modeling and control treatments for both the outcome and chronotime variables. Thus, there was no support for hypothesis one. This finding contradicts the findings of many of the modeling studies referenced in this paper, whereby modeling increased a participant's task performance.

There are a number of possible explanations for why we did not observe significant differences between the expert, novice and control treatments. First, the expert and novice modeling may have contributed to a false sense of expertise among participants. That is, by watching the modeling movie, participants became overconfident in their ability to play the game. To further support this explanation, data from the debriefing shows that six participants mentioned that the modeling movie contributed to them ignoring the program documentation. As one participant said, "I forgot about the instructions after watching the movie."

A second explanation suggests an opposite phenomena for the control. Instead of having a false sense of expertise and being overconfident in their ability to solve the task, the control group struggled with the problem. Thus, they may have had to use a greater set of problem solving heuristics and learn more from their trial and error. Although the finding was not significant, the control took longer (M=1121 seconds) to complete the task than either the expert (M=795 seconds) or the novice (M=634 seconds). This may indicate that the control was thinking more about the task than either the expert or novice.

A third explanation is the nature of the task, a computer game. While none of the participants had ever played WITICSD, a number of participants indicated that they had played other computer or video games before. Thus, the successful performance of the control group may be due to the skills and strategies participants developed while playing other computer games.

A fourth explanation is orienting activities. Perhaps the orientation and instructions given to each participant revealed too much game strategy, especially for the control group.

We found no support for our second hypothesis either. Our second hypothesis predicted that novice modeling would result in better task performance than expert modeling. For this analysis, we used the same outcome and chronotime dependent variables as in hypothesis one. A one-factor ANOVA analyzed the variables. There was no significant difference between novice and expert modeling.

The lack of difference between the novice and expert modeling may be caused by the novice group not observing successful task completion. We anticipated that the novice modeling would result in stronger performance since the participants would learn to avoid the common mistakes novices tend to make. However, the novice in the novice modeling movie did not successfully complete the task, whereas the expert in the expert modeling movie did. Thus, participants in the novice group may not have had a clear idea of how to recognize successful task performance.

Hypotheses Three and Four

Hypothesis three predicted that expert and novice modeling would result in better use of key task strategies than the control, and hypothesis four predicted novice modeling would result better use of key task strategies than expert modeling. As defined above, we created a dependent measure called effectiveness by scoring the participant's use of witness, informant, scanner, and note taking. Thus, we compared expert and novice modeling to the control by examining the effectiveness. A one-factor ANOVA analyzed the variables.

A significant difference (Df 2:42, $F=6.32$, $p<.01$) was found between the expert ($M=.809$), novice ($M=.841$) and control ($M=.693$) treatments. Additionally, a Fisher PLSD test revealed that novice was significantly different from control (.088, $p<.05$) and that expert was significantly different from control (.091, $p<.05$). Thus, hypothesis three has support. While hypothesis four appears supported, with novice modeling having a slightly higher mean than the expert modeling, a follow-up Fisher PLSD test between expert and novice yielded no significance.

Although we found no significance with hypothesis one and two, the significance found in hypothesis three identifies a key effect of the expert and novice modeling. From the results, we can infer that participants who viewed a model learned to use the key task strategies better than the control. Additionally, there is slight evidence that the novice group learned to use the key task strategies better than the expert group.

One would expect that if participants used the key task strategies effectively, they would successfully complete the game. However, the data show an incongruence between hypothesis one and three, and hypothesis two and four. It is possible to explain this incongruence because while participants in the expert and novice modeling treatment groups may have used key strategies more effectively than the control group, we have no direct way of knowing how they interpreted the information gained from exercising those strategies. Interpretation can only be inferred by a participant's successful completion of the game. If a participant successfully completed the game, then we can infer that they were successful in interpreting the clues. The key task strategies are only a means of uncovering clues necessary for successful completion. Thus, they have only a partial role in predicting successful completion.

Hypotheses Six through Eight

Our fifth hypothesis predicted that novice and expert modeling would result in stronger articulations than the control. We used a one-factor ANOVA to analyze the variables. We found no significant difference, indicating that neither novice nor expert modeling resulted in stronger articulations by the participant. Hypothesis five had no support.

Hypothesis six predicted that novice modeling would result in stronger articulations than expert modeling. A one-factor ANOVA analyzed the variables. There was no significant difference, thus the novice model did not cause stronger articulations than the expert model. We did not support hypothesis six.

Our seventh hypothesis was similar to the third hypothesis except we predicted that participants with strong articulations would use key task strategies more effectively than those with weak articulations. Independent raters scored the quality of articulations as either good or bad. Thus, we compared the good and bad articulations with effectiveness using a one-factor ANOVA. There was no significant difference, indicating that the quality of articulations did not affect the use of key strategies. Hypothesis seven had no support.

The explanation of why there was no difference for this hypothesis is similar to the explanations presented for hypotheses one and two. It is possible that the novice and expert modeling caused a false sense of expertise in participants, resulting in weak articulations for some. Additionally, the orientation activities may have provided too much information about how to play the game.

Hypothesis eight predicted that strong articulations would result in better task performance than weak articulations. For this analysis, we used the outcome and chronotime dependent variables used in hypothesis one and two as a measure of task performance. We also used the same articulation ratings found in hypothesis six and seven. A one-factor ANOVA analyzed the variables.

The results of this analysis were significant for both outcome (Df 1:43, $F=4.648$, $p<.01$) and chronotime (Df 1:43, $F=10.078$, $p<.01$). A Fisher PLSD test (.449, $p<.05$) revealed that participants with articulations classified as "good" had a mean outcome score of 2.435 while "bad" articulations had a mean outcome score of 1.727. A Fisher PLSD test for chronotime (3.908, $p<.05$) showed that the mean chronotime for "good" articulation was 6.087 while mean chronotime for "bad" articulation was 1.909. On the basis of these results, there was support for hypothesis eight -- strong articulations contribute to successful task performance.

This finding shows the importance of designing instructional interventions that contribute to forming strong articulations, since strong articulations are a good predictor of success. We should consider designing instructional interventions with the goal of enabling the learner to form strong articulations. This strategy contradicts the traditional concern for the terminal goal -- successful performance on a task. Facilitating successful performance was our paradigm when we designed the expert and novice modeling movies. An articulation-focused design strategy changes our paradigm to where we are more concerned with enabling learners to talk about how they solve problems rather than strictly focusing on enabling them to complete the task successfully.

Summary and Conclusion

The results of this study offer a number of interesting findings. We were unable to replicate the results found in previous modeling studies in which modeling enabled participants to perform better on a task. We also found no difference between the novice and expert groups in terms of task performance. However, we did find that novice and expert groups used key task strategies more effectively than the control group, and that there may have been only a slight difference between the novice and expert groups.

Our articulation task yielded similar results. We found no differences for the expert, novice and control treatments on the quality of the articulations. Additionally, participants with good articulations did not use key task strategies any differently from participants with bad articulations. However, participants with good articulations performed better on the task than participants with bad articulations.

Why didn't our findings support our many of our key hypotheses? We believe the main reason is the effect of the orienting activities. In order to make sure participants were technically able to use WITICSD, we conducted an extensive set of orienting activities common to all treatment groups. While we accomplished our goal of enabling participants to be technically competent, we may have told them too much. This might account for the lack of difference in task performance and articulation quality between all treatment groups.

There are two key implications from our study. First, cognitive modeling, regardless of the verbalization technique used, aids learners in adopting key task strategies. Thus, one should adopt cognitive modeling as an instructional strategy if the instructional objectives require the learning of heuristics. Second, since the quality of articulation is a predictor of task performance, we should design instruction to achieve quality articulations. Learners who can explain how they will solve a problem will experience more successful task performance.

Future research in the area of cognitive modeling should continue to explore variations in verbalization and their effects. Researchers should take time to consider the orienting activities, especially when working in a computer-based training environment. Additional research should discover how to facilitate quality articulations in instructional programs.

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Appendix A - Instructions Transcript

You will be playing a computer game called Where In Time Is Carmen San Diego. The object of the game is to catch a thief who has stolen a historical treasure.

In order to catch the thief, you must do three things:

1) You must gather clues to determine the thief's identify and to follow the thief's trail. Clues are gathered by using the search button, followed by either the Witness, Informant or Scanner buttons. The Witness and Informant buttons may contain clues about the thief's identity and his or her next destination. The Scanner button contains clues only about the thief's next destination.

2) You must follow the thief's trail from country to country. The Travel button enables you to travel to the next destination. Use the clues you've gathered to determine the next destination.

3) You must obtain an arrest warrant before arresting the thief. Arrest warrants can be obtained through the Data, then Evidence buttons. Record the clues you've gathered and use the Compute button to determine if the clues match a criminal and enable you to obtain an arrest warrant.

Here are some hints for playing the game:

1) It's a good idea to keep notes on paper as you gather clues.

2) Remember to work quickly and efficiently - you only have a certain amount of time to complete the task. Time is subtracted only when you a) travel from one location to another (here the time used is approximately 3-5 hours), b) obtain clues from the witness, informant or crime scene scan (here the time used is approximately 1 to 2 hours), or c) compute the evidence to try and obtain an arrest warrant (here the time used is 1-2 hours). No time is counted against you when you look up information from the reference sources.

3) You'll know when you have tracked the thief successfully when you see suspicious persons. The suspect you're tracking uses other gang members to check you out when your are getting close. If you interrogate a witness, informant or crime scene and they know nothing, you're probably in the wrong location. You'll then have to backtrack to the previous location to get back on the trail of the criminal.

4) When the criminal is at the same location your are, he or she launches a sneak attack against you. Make sure you have your warrant when this happens or else the criminal will get away. If you have your warrant, look to other sources of clues to find the criminal.

5) The key to tracking the criminal is deciphering the clues you find. You can decipher clues with the New American Desk Encyclopedia. Be sure to look at the "How To Use" section in the Encyclopedia.

Here's an example of how to acquire clues and evidence:

For example, let's say you use the Witness button and the clue is, "She wanted to talk with Dag Hammarskjold about economy." You could then look up "Hammarskjold" in the encyclopedia and find out he was a Swedish stateman in the 1900's. This clue would tell you the criminal's next destination is probably Sweden in the 1900's.

In addition to this clue, there is another button called More. You can click this button to get evidence about the criminals identity. For example, if the clue is "She just finished reading the book 'Animal Farm'.", you would go to the evidence selector by clicking the data button. You would then select each author, and look up in the encyclopedia if that author wrote 'Animal Farm'. So in this case, we would find George Orwell and keep him selected as a piece of evidence.

Appendix B - Transcription of Expert Movie

This movie is a demonstration on how to play Where in Time is Carmen San Diego. My name is Peter and I'll be showing you how to play the game. In this case the Indian Constitution has been stolen from India in 1947 by an unknown male. I have written down these facts in my notebook. The Federal Time Commission has given us 33 hours to solve the crime. We'll begin our investigation by searching for clues at the scene of the crime. I'll first investigate the witness. Here I find that the thief wanted to join a group called the Samurai. This gives me some information as to the next destination of the thief. Samurai, if I look 'em up in the Desktop Encyclopedia, are from Japan during the years 1000-1600 A.D. I'll write this down in my notepad for future reference. The 'More' button gives you clues as to the identity of the thief. Here (the more button) I get the clue that the thief had hazel eyes, and I'll write that down on my notepad as well. When I uncover data about the thief's identity I'll want to record them in my evidence folder. I look back in my notes and I see that one of the clues is that the thief is a male. I'll enter male under the sex option. I also know that the thief's eyes are hazel, so I'll click the eyes button until hazel appears. I won't compute yet to get an arrest warrant because I don't have enough information and it would just waste valuable Chronotime. so I'll continue my search.

The next place I'll investigate is the informant. Here I learn the thief wanted to spy on the Anu tribe. Once again this clue will give me some idea as to the location the thief went to next. And if I look up the Anu tribe in the Desktop Encyclopedia, I'll find that the Anu tribe was part of Japan as well, so I can deduce from my Samurai clue and this clue that the next destination of the thief is Japan. When I click the 'Travel' button, I'll see that Japan is one of the destinations, and that's where I'll follow the thief to next. Notice that I did not go to the 'Scanner' for any clues. This would be a waste of Chronotime since the 'Scanner' only gives me clues as to the thief's next destination, and I was already able to deduce the thief's next destination based on the two clues I received previously.

As in the previous location. I'll start my search by going to the Witness. O.K., a V.I.L.E. henchman has been detected. This is feedback the game gives me to tell me I have correctly followed the thief to the next destination. If I hadn't followed the thief to the next destination, the witness would have said to me, he had never heard of that person, or doesn't know anything about what I'm talking about. The witness tells me that the thief wanted to go to Lima, so I write this down on my notepad, and I look up Lima in my Desktop Encyclopedia, and find out that Lima is the Capital of Peru. This gives me a pretty good idea that the next destination of the thief is Peru.

I'll click the 'More' button to find out another clue as to the thief's identity. Here I find that the thief was holding a copy of The ^Hunchback of Notre Dame. This gives me some idea as to the author the thief liked. I'll immediately record this clue on my notepad as well as in my evidence folder. I'll click the 'Author' button and the first author that appears is Doysteyevski. I'll look up Doysteyevski in the Desktop Encyclopedia and see if he had anything to do with a book about the Hunchback of Notre Dame. He doesn't, so Ill have to go on to the next author. The next author is Victor Hugo. I look him up in the Desktop Encyclopedia and sure enough he is the author of The Hunchback of Notre Dame. Since I have three clues, this is usually enough to compute an arrest warrant, and sure enough the clues match a particular suspect.

Now that I have an arrest warrant for the thief, I have to track him as quick as possible to the next destination. From the clue the witness gave me, I know his next destination is probably Peru. So I don t need any more clues, and I'll travel directly to that location. Once again, I'll begin by searching for clues...ahh, I've found another V.I.L.E. henchman this means I still must be on the right track of the thief. The clue the witness gives me is that the thief wanted to meet the founder of the Capetians. I write Capetians down in my notepad, and look it up in my Desktop Encyclopedia. The Capetians are from France, so I can be pretty sure that the next destination of the thief is France. Since I'm pretty sure of that clue, I won't waste valuable time searching for other clues; I'll go directly to the thief's next destination.

I'll start once again by searching for clues at the witness. It looks like the thief is trying to kill me. This means he must be at one of the other sources of information at this destination. It also means that if I don't have my arrest warrant, I'd better go get it. Otherwise, I'll be charged with a false arrest. But since I havc my arrest warrant, I can go searching for the thief to try and catch him. Let's try the scanner to see if that will locate the thief. There he is, now the capture robot will go do the work. Good, we've captured the thief. We'll now send the data to the crime computer to verify his identity, and we'll get a congratulatory message from the Chief. That's how you play the game Where in Time is Carmen San Diego. Remember to record notes of clues you uncover during your search, and to use the Desktop Encyclopedia to interpret those clues and determine the next destination or identity of the thief. Also remember to get an arrest warrant before capturing the thief. now be given a chance to play the game yourself. Good luck.

Appendix C - Transcription of Novice Movie

"In this demonstration we'll be watching a first-time player play the game Where in Time is Carmen San Diego? My name is Peter and I'll be commenting on the player's performance as we watch the game. In this case an unknown male has stolen the Indian Constitution from India in 1947. The player has proceeded to the scene of the crime, and has thirty-three hours in which to solve the case. Let's watch as the player begins her investigation.

Here we see the player searching for clues at the witness. This particular clue about a gang of Samurai gives the player a tip about where the thief went to next. However, the player does not write down the clue or does not look at the Desktop Encyclopedia in order to decipher the clue. While the player was at the witness, she missed clicking on the 'More' button. The 'More' button would have given her a clue as to the identity of the thief. This would have helped her to get an arrest warrant. But now we see that she wants to go travel somewhere.

Without deciphering the clues the player received at the witness, regarding the Samurai gang, she has travelled randomly to the United States. Let's see what happens now. As we can see the witness has nothing the tell the player. This means the player has travelled to the wrong location. What she needs to do now is get back to her previous location and get back on this trail of the thief. The player has now returned to India in the 1900's, therefore she is back on the trail of the thief. Notice the Chronotime is at 27 hours. Each time the player travels to a destination, or obtains a clue from the witness, informant, or scanner, time is counted off the total chronotime. This means you have to be sure of where you're travelling, or to be efficient in searching for your clues so you do not run out of chronotime. Running out of chronotime means you will not be able to catch the thief. Let's watch now as she continues her search .

Here the player gets the clue of the Shinto Shrine. She writes it down on her notepad and looks up 'Shinto' in her Desktop Encyclopedia. Once again the player forgets to click the 'More' button under the witness to get a clue as to the identity of the thief.

In the informant, the player finds the clue of the Golden Hall of Haruji. She writes these words down in her notepad, and looks up both Golden Hall and Haruji in the Desktop Encyclopedia. She finds nothing for these terms. Based on the clues she received from the witness and the informant, the player seems to have deduced that the next destination of the thief is Japan. What we have just witnessed is the appearance of a V.I.L.E. henchman. These V.I.L.E. henchmen check up on you when you are following the thief correctly. Thus, the player has correctly followed the thief to Japan. In the informant the player gets the clue of Austin & Emma. This clue gives the player some idea of where the thief travelled to next. She writes the clue down on her notepad, and looks up Austin in the Desk Encyclopedia. Once again the player missed clicking on the 'More' button to get a clue as to the identity of the thief. In the witness, the player gets the clue of Rugby. She writes Rugby down on her notepad and looks up Rugby in the Desk Encyclopedia, however, cannot find an entry for it. Once again, the player has not clicked on the 'More' button in order to get a clue as to the identity the thief. Without these types of clues, the player will not be able get an arrest warrant, thus, the player will not be able to win the game. It's very important that, when you do not have an arrest warrant, you always click the 'More' button to get some idea of who the thief is.

It seems that from the clues of Austin & Emma and of Rugby the player was able to deduce that the next location that the thief travelled to was England. Let's see if that turns out to be correct. ^once again the V.I.L.E. henchman has appeared, so the player has successfully tracked the thief to the next destination. Here (under button which has just been pushed and illustrated on the screen) the player receives the clue of a mousetrap. She writes it down on her notepad and looks it up in the Desk Encyclopedia, but finds nothing. I tend to ^feel that the scanner is a waste of time, most of the clues that you need to ^follow the thief can be found in the witness and informant. Plus, the scanner will never have a clue as to the identity of the thief. I usually only the use the scanner as a last resort if I cannot figure out the destination of the thief from the clues I obtain in the witness and informant. In the witness the player gets the clue Titanic. She writes it down on her notepad, and looks it up in the Desk Encyclopedia and finds a reference for it.

Based on the clue of the Titanic, the player has deduced that the next destination of the thief is England in the 1900's. Note that back in the witness, she did not click the 'More' button once again. This denied her of an important clue as to the identity of the thief, which would have helped her get an arrest warrant. When a life- threatening trap has been set against the player, as the one that we just saw, this means that the thief is somewhere at this destination and that the player has to try to find the thief's whereabouts at either the witness, informant or scanner. It appears that the player has finally realized that she needs an arrest warrant to catch the thief. Since the player did not investigate any of the 'More' buttons to obtain clues as to the identity of the thief, the only clue she has is that the thief is a male. Usually~ you need three or more clues in order to obtain an arrest warrant. So I do not think this player will be getting an arrest warrant this time. As I mentioned, only one clue is insufficient data, and returns a whole list of possible suspects. Thus an arrest warrant cannot be issued.

Another trap has been uncovered, the player is now getting close to capturing the thief. The player has located the thief, and now the capture robot will be sent to make the arrest. Well, the player has successfully tracked Russ T. Hinge but unfortunately, without an arrest warrant, Russ T. Hinge is allowed to go free. Although the player made a minor mistake at the beginning of the game, she was able to successfully track the thief from destination ~. destination. However, she did forget to acquire clues as to the identity of the thief which prevented her from getting an arrest warrant. You'll now be able to have a chance to play the game Where in Time is Carmen San Diego. Good luck.

Appendix D - Data Collection Instrument

Subject:
Treatment:
Coach Name:
Observer Name:

Start Time:

End Time:

Task #2

Destinations	1	2	3	4	5	6	7	8	9	10
Location/date										
Chronotime										
Witness										
Informant										
Scanner										
Note taking										
Reference										
Program doc.										
Select clues										
Select Inferred clues										
Arrest warrant attempt										
Arrest warrant?										
Task complete.										
False arrest										
False leads										