International Education Journal Vol 3, No 4, 2002
Educational Research Conference 2002 Special Issue
http://www.flinders.edu.au/education/iej

Computer Adventure Games as Problem-Solving Environments

David D Curtis
School of Education Flinders University *david.curtis@flinders.edu.au*

Michael J Lawson
School of Education Flinders University *mike.lawson@flinders.edu.au*

Claims that computer-based adventure games are productive environments for the development of general problem-solving ability were tested in a study of 40 students' interactions with a novel computer-based adventure game. Two sets of factors that are thought to influence problem-solving performance were identified in the literature – domain-specific knowledge (schema) and general problem-solving strategies. Measures of both domain-specific knowledge and general strategy use were developed and applied in the study. A cognitive model to explain performance is developed in which there are complex relationships among key concepts. General strategies were found to have important influences on problem-solving performance, but schema was negatively related to performance. The implications of these findings for both classroom practice and future research designs are discussed.

Computer adventure games, problem-solving ability, strategies

INTRODUCTION

The claims made about benefits that students might derive from the use of adventure games can be categorised into three groups: those about social interaction, about language, and about problem-solving. Several authors have suggested that children develop greater social skills through their interactions while playing adventure games (Craig, Podmore, Atmore, & Ashworth, 1987; Heron, 1987; Sherwood, 1988). Sherwood (1988, p.299) noted that: "The computer fosters cooperative work among students as the goal is not necessarily to complete but to problem solve. Students who collaborated on the adventure game often taught each other. Such computer oriented group work provided a positive socialising experience."

Others have claimed, on the basis of observational studies, that students develop enhanced language skills (Rice, 1985; Sherwood, 1988; Strack, 1985; Thompson & Duncan, 1988; Unwin, 1983). For example Unwin (1983, p.149) argued that "As a young person plays an adventure game, he develops such important skills as spelling, reading comprehension, critical thinking, and creativity".

It has been argued that adventure games often include puzzles that need to be solved in order to complete the game (Heron, 1987); that students need to apply knowledge derived from "life and literature" (Rice, 1985); that students must use general problem-solving skills like inferring, monitoring, and deductive reasoning (Sherwood, 1988); and that adventure games encourage application of metacognitive skill (Henderson-Lancett & Boesen, 1986). For these reasons, adventure games are claimed to have application across a range of curriculum areas (Bell & Scott, 1988; McArdle, 1985). Taken together, this final group of assertions support the view that students become better problem-solvers following exposure to adventure games.

The focus of this study was the claims for enhanced problem-solving performance flowing from the use of computer-based adventure games. Many of the studies cited above are anecdotal reports of observations made by teachers and others in classrooms as children used adventure games. In one of the few empirical studies located in a review of the literature, Grundy (1988) found that adventure games do have potential as effective problem-solving environments, but that this potential is not realised because children are often able to invoke techniques for avoiding the use of transferable strategies. Grundy noted that in many adventure games children are able to avoid reading for detail and are often not required to assimilate new information for later recall and use. The results of Rhodes' (1986) study also cast doubt on some of the claims made for adventure game use. Rhodes found no differences in comprehension skills between a group of students who used adventure games and a control group. Classroom use of many adventure games for influencing problem-solving is also limited because the programs usually do not include guidelines to suggest how they might be used, what problem-solving strategies could be developed, or what other experiences might be arranged to support their use (Grundy, 1988, p.21). There is, therefore, uncertainty about the status of the view that use of adventure games will result in improved problem-solving performance. The research basis for this claim is not extensive and is generally not embedded in a suitably developed conceptual framework that would provide the background for relating particular features of adventure game use and processes invoked during problem-solving.

COGNITIVE PERSPECTIVES ON PROBLEM-SOLVING

Problems and Problem-Solving

Mayer (1992) presented a useful definition of problem-solving:

> *Problem solving is cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver.*

Greeno, Collins and Resnick (1996) outlined three major theoretical stances on learning and problem-solving that they termed associationist/behaviourist/empiricist, cognitive/rationalist, and pragmatist/situative/sociohistoric. Of these, the variants of the cognitive and situative appear to be most useful in developing understandings of individuals' development of problem-solving capability.

In the information processing framework for problem-solving developed by Newell and Simon (1972), a problem exists when the current arrangement of problem elements (the current state) is different from the desired arrangement (the goal state) and operators that can effect the transition between the two states are not readily available. The problem solver's task is to find the operators that will enable the current state to be transformed into the goal state. The states of an adventure game are the set of locations and their descriptions, the set of objects and their positions and functions, and the set of restrictions on what actions can be taken. The problem operators are the commands that players issue to effect a change in the game state to bring it closer to the goal. Using the Newell and Simon model, the strategic nature of the student's actions (moves) is likely to have a major influence on the success of the problem-solving attempt.

However, more recent research has also highlighted the important influence that the student's store of knowledge has on comprehending the situation, selecting moves, and thereby affecting the outcome (Schneider, 1987, 1990).

The strictly cognitive models of problem-solving, with an emphasis on abstract representations inside the problem-solver's head, is criticised by researchers who have investigated problem-solving in 'real world' situations. Scribner (1986) described the processes used by packers in a warehouse and Lave (1988) showed how shoppers made decisions about which products, packaged in different amounts, represented 'best buys'. The individuals in these studies performed skilfully, but did not use abstract processes. Rather, they manipulated concrete materials, used non-formal practical representations, and employed low mental load strategies.

Problem-solving ability is defined as "cognitive processing directed at achieving a goal when no solution method is obvious to the problem-solver" (Mayer & Wittrock, 1996). This definition emphasises neither general processes nor the individual's knowledge base. It may be taken to include either or both in effective problem-solving performance.

Expertise, Knowledge, and Strategy Use in Problem-Solving Performance

Chi, Glaser, and Rees (1982) claimed that success in problem-solving depends on access to a well-developed and extensive knowledge base. Experts have richly elaborated knowledge bases and they use these early in problem-solving to develop a representation of the problem task that then directs the moves used to solve the problem. Thus, Chi et al. (1982) argued that domain specific knowledge is of major importance in expert problem-solving. Others also support this view (Larkin, 1985; Schneider, 1987). Sweller (1990) went further and argued that:

> Subsequent work on expertise in areas such as physics and mathematics supported the suggestion that domain-specific-knowledge rather than general problem-solving skills differentiated novices from experts. (Sweller, 1990, p.412)

Sweller postulated that experience in a domain results in the formation of a schema for that domain that includes a knowledge base and a set of highly automated rules. The schema enables problem classification according to previously encountered solution procedures and the associated rules can then be used to direct performance. If this is so, schematic knowledge should be strongly associated with a high level of success in problem-solving.

Other researchers have argued that it is necessary to qualify this view of the dominance of prior knowledge as a factor in problem-solving performance. They have argued that, through experience in solving problems, students also use and develop a set of more general skills that they may apply in new situations. Bereiter and Scardamalia (1986) pondered the question of how novices, with limited domain-specific knowledge, transform themselves into experts. They argued that some people are expert at becoming expert and that they do this by the use of strategies. This view is taken further, with claims that students can be taught to use a set of general problem-solving skills (in a domain), and that when the skills are well developed, students will transfer them to other domains. A number of authors have reported improved performance following strategy instruction (Bereiter & Scardamalia, 1987; Charles & Lester, 1984; Clements, 1990; Hembree, 1992; Lawson & Rice, 1987; Paris, Wixson, & Palincsar, 1986). There is, however, more argument about the extent to which students can spontaneously transfer strategies developed in one area to another, so that even when subjects have knowledge available, frequently they only apply that knowledge when reminded of its availability and relevance (Gick & Holyoak, 1983; Ross, Ryan, & Tenpenny, 1989).

Thus there are two different positions: one that holds that effective problem-solving depends upon a well developed knowledge base and another that relies upon generally applicable strategies. Despite the identification of these two contrasting positions it is not necessary, or even helpful, to opt for only one or other of schema induction or strategy use to explain problem-solving performance. Siegler (1990) argued strongly that schematic knowledge and strategy use interact and that this interaction requires acknowledgment of the contribution of both sets of factors to the students' outcomes. In the initial acquisition of knowledge, strategy use is important, and in later access to and use of that knowledge, it is again a factor (Alexander & Judy, 1988; Chi, Hutchinson, & Robin, 1989; Chi & VanLehn, 1991; Prawat, 1989).

Thus the literature suggests that there are two major sets of influences on problem-solving, schematic knowledge and strategy use, that they interact, and that they need to be considered in explanations of problem-solving performance. However, schematic and strategic knowledge cannot be the elemental determinants of performance. Schematic knowledge must arise from experience and also be related to ability. Strategy use is very likely to be related to ability and may also depend upon experience.

In the adventure game context it was hypothesised that both general ability and experience of adventure games would enhance problem-solving skill, and from this it was predicted that more adventure game experience would result in superior adventure game performance. It was also postulated that experience in use of adventure games would affect students' knowledge of these games and their use of general problem-solving strategies. These two factors, separately or in concert, could lead to enhanced performance. These assumptions are summarised as a set of hypotheses:

1. Higher levels of ability will lead to enhanced performance;
2. More experience of adventure games will lead to enhanced performance;
3. Higher ability will be associated with greater general strategy use;
4. More experience of adventure games will lead to greater schematic knowledge;
5. Greater use of general problem-solving strategies will lead to superior performance;
6. A greater domain-specific (schematic) knowledge base will lead to superior performance.

These relationships are summarised in Figure 1. The two independent variables (Ability and Experience), the two mediating variables (Strategy use and Schema), and the dependent variable (Performance) are all latent constructs. They are not measured directly but are indicated by a range of manifest variables. For clarity, the manifest variables that are used to operationalise the constructs have not been included in the diagram.

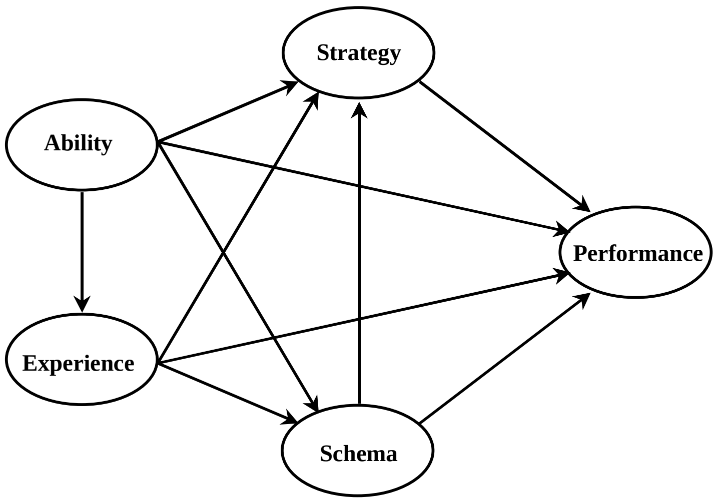

Figure 1. The hypothesised model of relationships among Ability, Experience of computers and adventure games, Schema for adventure games, Strategy use and Performance on adventure games

In the model, some relationships in addition to those specifically posited in the hypotheses were tested. A path was included from Ability to Experience in order to detect whether there was a bias in the inclination of students of different ability levels to engage in the use of computers or adventure games. Two other paths have been postulated in the model to be tested. One is a path from Ability to Schema. The presence of this path would indicate that higher ability students induce adventure game schema more readily than students of lesser ability on the basis of a given amount of adventure game experience. Similarly, a path between Experience and Strategy use is proposed. Here the main hypothesis is that Ability is related to Strategy use, but that more experience of adventure games may result in greater application of general problem-solving strategies. This possibility is also tested by the inclusion of a path from Schema to Strategy use. The import of this path is that the influence of Experience may operate directly on Strategy use, but it may also operate indirectly through Schema.

The path model includes the possibilities that there are direct relationships between constructs, for example from Ability to Performance, but that there may also be indirect relationships, for example Ability may also influence Performance through Strategy use.

Thus, a model of problem-solving performance in adventure games was hypothesised that invoked strategy use and schematic knowledge as mediating constructs with cognitive ability and domain-specific experience as primary constructs. The ways in which these constructs were operationalised are described in the Method section of this paper, and the corresponding variable labels are shown in italics.

METHOD

Subjects

Participants in the study were 44 students from three metropolitan schools in Adelaide. The students ranged in age from 12 to 15 years and they were in Years 7 to 10. Data from four students were lost due to equipment failure, leaving complete data for 40 subjects, of whom 18 were female.

Prior Knowledge and General Ability

In order to assess the extent of previous exposure to adventure games, students completed a self-report questionnaire in which they were asked about their experience of, and affect for, computers (*CmpExp* and *Affect*), and the number of adventure games that they had played (*AgExp*). The questionnaire also sought information on students' age (*Age*), sex (*Sex*) and knowledge of meanings for 20 words that were taken from the adventure game (*AWK*). In order to generate information about students' prior schematic knowledge of adventure games, the questionnaire also presented a location description from another adventure game as it might have appeared on screen. Students were asked to generate a list of moves that they thought would be appropriate (*Elab*), and then to select the move that they thought would be the best one (*Action*). This list of moves and the suggested best move were scored to establish a measure of schematic knowledge for adventure games.[1]

Students were classified as novice, intermediate or experienced players based upon the number of adventure games that they indicated they had played. Those who had played none or one game were classified as novices, of whom there were 10; those who had played two

[1] All material used in this study, including the adventure game program, are available from the first author

or three games as intermediate, of whom there were 20; and those who had played four or more games as experienced, and there were 10 in this category.

Students also completed a standard word knowledge test (Australian Council for Educational Research, 1989) to provide an estimate of verbal ability (*WKTF*). This was taken as a proxy for general ability.

At the conclusion of the session in which students completed the questionnaire and the word knowledge tests, each student was given a copy of the instructions for playing the adventure game. They were asked to read the instructions before presenting for the adventure game session which was held one week later.

The Adventure Game

For this study a new text based adventure game, The Ancient Abbey, was developed. It has 34 locations and six objects that must be found in order to complete the game. It is structured so that the first two objects can be found simply by going to their initial locations. Both must be found to retrieve the third object, and this is required to move to the section of the game where the remaining objects are placed. In this area, locating the sixth object requires the player to hold the fifth, and to get this, object four must already have been obtained. In this way, the number of objects located and the number of game locations visited provide an index of performance in the game.

The program includes data collection code. As the player makes a move, the time of the move, the player's location, and the command issued are recorded in a text file.

Think-Aloud Protocol Generation Training

Immediately prior to the adventure game session, students were given training individually in the generation of a concurrent think-aloud protocol. In the training, which used another text-based adventure game with the same screen layout as the experimental game, the researcher modelled the think-aloud process by reading relevant information from the screen, by articulating possible moves, and by selecting and giving reasons for the chosen move. Students were then asked to continue with the game. During the training, if students did not give reasons for their moves, they were reminded to do so, and in some cases the process was modelled again. The duration of this training was approximately 15 minutes, but varied depending upon the extent to which students demonstrated their ability to articulate reasons for their moves. The experimental game was commenced when the researcher was satisfied that the participant would be able to generate a useful protocol.

Adventure Game Data Collection

When students presented for the adventure game session, they were given a copy of the adventure game instructions and a blank 'map' (a sheet of paper with a grid of boxes) that could be used to keep records of their progress. Students were not told to use this, it was simply available for those who chose to use it. Further, while students played the game, they were reminded of the need to provide a concurrent think-aloud protocol. The think-aloud protocols were audio-tape recorded and later transcribed. The transcripts were analysed for evidence of students' use of a variety of strategies, including game specific strategies such as saving the game if they thought that the next move might be dangerous, and more general strategies like making inferences from information presented on screen, planning a sequence of moves, or monitoring performance. The strategies coded in the analysis of transcripts are shown in Table 1.

A criterion measure of student performance in the game was required. The adventure game is in effect a sequence of small puzzles. In choosing to move from one location to the next, there is a description of the location and an indication of possible directions. Using the hints provided in the location descriptions helps users to decide courses of action. In order to complete the game, six objects had to be collected. The first two could be found by visiting their locations and issuing the command to take them. However, one of the objects was a key that had to be used to open a door to a location where other objects were available. Thus the number of objects collected reflected the degree of completeness of the game solution. Thus the two variables, *Locatns* and *Objects*, were used as indicators of performance. Other information collected during students' use of the game were the extent to which they used maps (*Maps*) and the number of moves that they made (*Moves*).

Table 1. Summary of strategic behaviours coded in transcripts of students' protocols recorded during adventure game play

	Planning		**Monitoring**
P1	Single moves with no forward planning indicated.	M1	Recall that a location has been seen before.
P2	A move for which a goal is specified.	M2	Acknowledgment of a memory limitation.
P3	An adventure specific move like saving game status.	M3	Acknowledgment that an error has been made.
		M4	Summary reflection on performance.
	Recognition		**Errors**
R	Recognition of the significance of an object.	E1	Error in reading text from screen.
	Inference	E2	Error in recall of a location.
I1	Infers use for an object when it is first encountered.	E3	Error in using a direction. Says East but moves West.
I2	Infers use for an object when prompted by a situation.		

Data Analysis

Two approaches were taken in the analysis of the data collected during this investigation. First, in order to ensure that the data were free of errors, a range of descriptive statistics were computed. The hypothesised relationships among the variables were investigated using *t* tests to compare independent samples. Although this method provides a useful exploratory approach to data analysis, it lacks the power to investigate a problem that is multivariate in nature. Second, path modelling was undertaken in order to establish a more complete understanding of the explanatory constructs invoked in the study, and the focus in the remainder of the paper is on the conduct and interpretation of the path analysis.

In order to further examine the relationships among the set of variables, the path model shown in Figure 1 was tested using Partial Least Squares (PLS) path analysis with the program PLS Path (Sellin, 1987). Alternatives available for this analysis included multiple regression analyses and the use of Structural Equation Modelling (SEM). The former was tried but rejected because of the detection of multicollinearity among independent variables. The latter method requires large sample sizes and assumes multivariate normal distributions among variables. Given that the sample size was relatively small at 40, PLS was the chosen analytical method. Because it does not make distributional assumptions, PLS has the disadvantage that standard errors are not computed from a distribution. However, estimates of standard errors are provided through the use of the jack-knifing technique, and so it is possible to infer the significance of the variables included in the model. Path analysis using

PLS shares with SEM the capacity to define the problem in terms of latent constructs and manifest variables and to explore theoretically interesting relationships among the latent constructs.

RESULTS

Initially a path model was specified that included all possible paths among latent variables as shown in Figure 1. From two to eleven manifest variables were used as indicators for each latent variable. In an iterative refinement of the model, some manifest variables were removed from the model when their loadings were found to be low compared with the jack-knife standard error of the estimate. Some paths between latent variables were also removed when their magnitudes were low compared with the estimated standard errors. The criterion for retention for both manifest variables and for paths was that the estimated magnitude of the manifest variable loading or the path coefficient had to be more than twice the jack-knife standard error.

During the refinement of the model five manifest variables were removed from the Strategy use latent construct. The variables removed included the three behaviours coded as Errors. These involved errors in reading information (*E1*), recall of information (*E2*), and errors in making moves (*E3*). Two monitoring behaviours were also deleted from the model. These were *M1*, recall of a location, and *M2*, recognition of memory limitation. Another variable of interest, *P1* – making moves without articulating a purpose – had not been included in the model as this variable represents a lack of strategic activity rather than the use of a particular strategy.

Several paths between latent constructs were also removed because they proved to be non-significant. A path had been hypothesised between Ability and Experience. This had been included in case there had been bias in that high ability students might have been more (or less) inclined to play these games or otherwise to engage with computers. This path coefficient was 0.156 with a jack-knife standard error of 0.178, and so it was removed. It can therefore be concluded that there was no significant ability bias in the tendency to engage with computers or to play adventure games. The lack of a relationship between these variables enables them to be treated as independent exogenous constructs in the model.

The path from Experience to Strategy use was removed initially. The path coefficient was 0.125 and the jack-knife standard error was 0.180, indicating that the path must be regarded as non-significant. However, following the removal of the path from Schema to Strategy use (see below), this path was reinstated and its magnitude was marginally significant at 0.218 with a standard error of 0.108, the criterion ratio being 2.180.

A path had been postulated from Schema to Strategy use. It was hypothesised that having a schema for adventure games might enable the selection and deployment of particular strategies. However, the path coefficient was 0.190 with a jack-knife standard error of 0.230. While this path is of moderate magnitude, the relatively high standard error may indicate that more experienced players with better developed schemas use them directly in their solutions, while less experienced players with limited schematic knowledge may rely largely upon general purpose strategies. The relatively high standard error estimate of this path coefficient may be important in understanding the relationships that emerged in the analysis, and this matter is again raised in the Discussion section.

The results of this analysis following refinement are summarised in Figure 2.

Table 2 shows the results of the outer model – the loadings of manifest variables on their associated latent variables, with the jack-knife standard errors of those loadings and the ratios of the loadings to the standard errors. These ratios provide an indication of the consistency the loadings. For most latent variables, the sets of loadings are reasonably high, but for the Strategy use latent variable, the loadings are somewhat variable and the Q^2 statistic is rather low. This may suggest that there is considerable variation among participants in the particular strategies that they use.

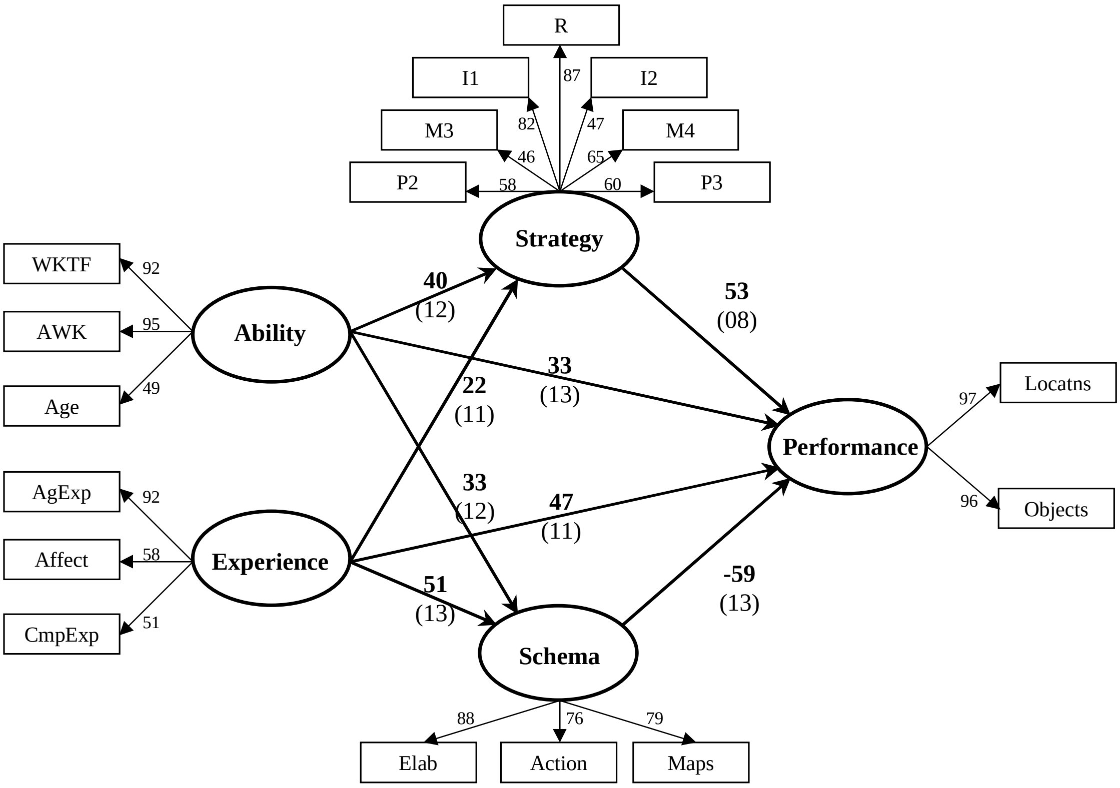

Figure 2. Results of a path analysis on the hypothesised model of adventure game performance (Coefficients are shown for inner model paths with standard errors in parentheses. Outer model loadings are shown without standard errors, given in Table 2).

Table 2. Loadings of Manifest Variables on Latent Variables in the Path Model

Latent Variable	Manifest Variable	Loading	Jack-knife Standard Error	Ratio of Loading to Standard Error
Ability	WKTF	0.921	0.034	27.088
	AWK	0.946	0.023	41.130
	Age	0.486	0.122	3.984
Experience	AgExp	0.919	0.024	38.292
	Affect	0.581	0.109	5.330
	CmpExp	0.513	0.115	4.461
Schema	Elab	0.879	0.040	21.975
Q^2 = 0.303	Action	0.763	0.069	11.058
	Maps	0.791	0.065	12.169
Strategy use	P2	0.542	0.189	2.868
Q^2 = 0.077	P3	0.532	0.148	3.595
	I1	0.787	0.111	7.090
	I2	0.473	0.126	3.754
	M3	0.526	0.129	4.078
	M4	0.695	0.270	2.574
	R	0.887	0.077	11.519
Performance	Locatns	0.966	0.009	107.333
Q^2 = 0.459	Objects	0.956	0.011	86.909

(The Q^2 statistic is an indication of the predictive power of predictor variables for the manifest variables associated with a given latent variable).

The results of the inner model, the paths among latent variables, are shown in Table 3. In each cell the path coefficients between latent variables, their jack-knife standard errors, and their ratios are tabulated. Also shown are the R^2 values for the predicted variables. The R^2 value for Performance is 0.590 indicating that the model is able to predict a high proportion of the variance in this construct.

Table 3. Estimated Path Coefficients, Jack-knife Standard Errors and Criterion Ratios in the Refined Model of Performance

		Endogenous (Predicted) Latent Variables		
		Schema $R^2 = 0.403$	**Strategy use** $R^2 = 0.227$	**Performance** $R^2 = 0.590$
Predictor Latent Variables	Ability	0.328 0.120 2.733	0.403 0.117 3.444	0.330 0.126 2.619
	Experience	0.513 0.131 3.916	0.218 0.108 2.019	0.473 0.111 4.261
	Schema			-0.590 0.128 -4.609
	Strategy use			0.534 0.080 6.675

Each cell has the path coefficient (Beta), the Jack-knife standard error, and their ratio

Table 4 shows the direct, indirect and total effects of the explanatory latent constructs on dependent ones. Both Ability and Experience are mediated through Strategy use and Schema. Ability has positive direct and indirect effects, while Experience has a positive direct effect, a small positive indirect effect through Strategy use, and a substantial negative indirect effect through Schema.

Table 4. Summary of Path Coefficients among Latent Variables

	Direct Effect	Indirect Effect	Total Effect
Schema			
Ability	0.329	.	0.329
Experience	0.513	.	0.513
Strategy use			
Ability	0.403	.	0.403
Experience	0.218	.	0.218
Performance			
Ability	0.329	0.212	0.351
Experience	0.473	-0.187	0.287
Schema	-0.590	.	-0.590
Strategy use	0.534	.	0.534

Discussion of Results

The positive relationships from Ability to Performance and Experience to Performance are expected. Similarly the positive paths from Ability to Strategy use, from Ability to Schema, from Experience to Schema and from Experience to Strategy use are also expected. The relative magnitudes of these paths are also of interest. Ability has a moderately strong path to Strategy use and Experience has a similarly strong path to Schema.

Of greater interest are the influences of the modelled constructs on Performance. Predictably, both Ability and Experience have positive direct influences on Performance. The quite strong positive path from Strategy use to Performance indicates that the use of general problem-solving strategies has been an important element in the mechanisms by which the participants in this study have been able to solve the problems posed within the adventure game environment. However, what is quite surprising is the strong negative path from Schema to Performance. At first glance, this result suggests that having a well developed Schema for adventure games is counter-productive to achievement, a proposition that makes no theoretical or practical sense. Even if an extreme information processing position was taken and it was asserted that problem-solving performance was a result only of the application of very general strategies, how could the acquisition of greater knowledge undermine performance?

In order to understand the unexpected relationship between Schema and Performance, the measures for Schema must first be reviewed. The manifest variables used to form the Schema latent construct in the study may not be as complete a representation of this construct as is desirable. Schema for adventure games was inferred from a scenario taken from another adventure game from which participants had been asked to generate a range of moves and from them to select optimal moves. These two variables are taken as indicators of an adventure games schema: those participants who had a well developed schema for adventure games were presumed to be capable of generating a greater number of moves and of selecting more productive moves. This appears to provide an indication of schematic knowledge, but it may not provide as complete a representation of it as is desirable. More detailed questions about possible courses of actions and expected outcomes may well have provided a more comprehensive indicator of this latent construct.

Two explanations are hypothesised for the observed negative path between Schema and Performance. First, it was assumed that the students participating in this study represented a range of experience from novice to some advanced level of expertise and that there would be a gradual transition in the use of knowledge and strategies with increasing experience. However, it is possible, that as experience grows, there is a change in the architecture of problem-solving and that a model that describes near-novice problem-solving is rather different from the model required to account for proficient or expert problem-solving. If this is so, then in the current study the hypothesised model is a conflation of two, and possibly more, models. There are indications in the current model that this may be the case. Two paths involving Schema, one from Ability and one to Strategy use, had rather high standard errors. In addition, the Q^2 statistic for the Strategy use latent variable was rather low suggesting that strategy use among participants was variable. It is possible that the very inexperienced participants, having no prior experience of adventure games, were forced to rely only on whatever general strategies they could to solve the puzzles that were part of the game and to develop an understanding of this particular game context from the descriptions provided. Those with more experience may have been able to use their knowledge base to make better strategy choices. This line of argument helps to explain the positive path from Experience to Strategy use and from there to Performance. It also suggests that for more experienced individuals, there should be a significant path from Schema to Strategy use. However, it does not explain the negative path from Schema to Performance.

A second related hypothesis is required. With more experience, schematic knowledge develops, and that knowledge enables the selection of efficient strategies. However, despite the range of experience reported among participants in the present study, it is suggested that their experience ranged from novice to perhaps competent, but that it did not include experts. The level of schematic knowledge available to the competent participants enabled them to make more effective use of general strategies, but was not automated to the extent that it could drive performance directly. Thus, in the composite model, those participants with better developed schemas used them to employ general strategies more effectively. Thus, for all levels of experience among participants there is a positive association between Strategy use and Performance. For complete novices, there is little schematic knowledge, while for their slightly more experienced peers, there is greater schematic knowledge but even greater strategy use. Thus, greater schematic knowledge is negatively associated with Performance.

Somewhat paradoxically, these hypotheses may support the views of Sweller (1999) that informational complexity and the application of general problem-solving strategies place a high cognitive load on individuals. The developing knowledge base may reduce the cognitive load associated with using the general strategies required to apprehend and understand the virtual environment being encountered and enable efficient use of those strategies during the problem-solving of non-experts.

These hypotheses have implications for research designed to elicit cognitive models of performance at various stages of the transition from novice to expert.

CONCLUSION

This study was designed to test claims that experience of adventure games leads to the development of general problem-solving skills. From the literature on problem-solving two possible factors, schema and strategy use, were identified that could influence problem-solving performance. Evidence for effects of adventure game experience on both schema and on strategy use were sought, and a model of their influence on performance was developed and tested.

The model of adventure game performance based on data collected in the study revealed that experience of adventure games leads to a modest increase in the use of general strategies and that the application of those strategies does lead to enhanced performance in a novel adventure game task.

However, it is not possible to assert that these strategies will be used by individuals when confronted with new problems in other domains. On this basis, it would be imprudent to advocate the use of adventure games in classrooms as vehicles for the development of broadly applicable problem-solving ability. Additional work is required to investigate whether the enhanced use of general strategies does transfer from adventure game environments to other problem domains that students might encounter in their classrooms and beyond.

In the past, general strategy use and schema were offered as alternative explanations for problem-solving performance, and a crude interpretation of the model developed in this study might be used to assert a case for the predominance of general strategy use in solving adventure game problems. However, it was argued in the discussion of the results that the model developed here may be only one of several that could be invoked to explain performance of individuals as they move from novice status through competence to expert. Thus no conclusion is suggested for the relative importance of general strategies and schematic knowledge. Instead, Siegler's advice is reiterated when he sought to show:

> ... how specific knowledge influences choices among strategies, how choices among strategies in turn influence the construction of specific knowledge, and how individual differences in both

> initial knowledge and cognitive style influence both choices among strategies and acquisition of further knowledge. (Siegler, 1990, p.74)

Thus, Seigler supports both the complementary roles of general strategy use and schematic knowledge and the notion that cognitive mechanisms may change over time reflecting growth in both schematic knowledge and the availability of general strategies.

It is suggested that further research is required in order to establish whether different cognitive mechanisms are associated with the various stages between novice and expert status. If individuals can be assigned to groups on this continuum, it may be possible to construct path models for each group and to compare the models. Alternatively, a longitudinal study may track individuals as their expertise develops over time within a domain.

REFERENCES

Alexander, P. A., & Judy, J. E. (1988). The interaction of domain-specific and strategic knowledge in academic performance. *Review of Educational Research, 58*(4), 375-404.

Australian Council for Educational Research. (1989). *ACER Word Knowledge Test. Form F*. Hawthorn: ACER.

Bell, S., & Scott, I. (1988). *Springboards: ideas for using computers in the classroom*. Melbourne: Nelson.

Bereiter, C., & Scardamalia, M. (1986). Educational relevance of the study of expertise. *Interchange, 17*(2), 10-19.

Bereiter, C., & Scardamalia, M. (1987). *The psychology of written composition*. Hillsdale, N.J.: Lawrence Erlbaum.

Charles, R. I., & Lester, F. K. (1984). An evaluation of a process oriented instructional program in mathematical problem solving in grades 5 and 7. *Journal of Research in Mathematics Education, 15*(1), 15-34.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 1). Hillsdale, N.J.: Lawrence Erlbaum.

Chi, M. T. H., Hutchinson, J. E., & Robin, A. F. (1989). How inferences about novel domain-related concepts can be constrained by structured knowledge. *Merrill-Palmer Quarterly, 35*(1), 27-62.

Chi, M. T. H., & VanLehn, K. A. (1991). The content of physics self-explanations. *The Journal of the Learning Sciences, 1*(1), 69-105.

Clements, D. H. (1990). Metacomponential development in a Logo programming environment. *Journal of Educational Psychology, 82*(1), 141-149.

Craig, B., Podmore, V., Atmore, D., & Ashworth, D. (1987, December). *Computers in the classroom: observations of children's social behaviour and collaborative group work.* Paper presented at the Australian Association for Research in Education / New Zealand Association for Research in Education Conference, Christchurch, NZ.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 15*(1), 1-38.

Greeno, J. G., Collins, A. M., & Resnick, L. B. (1996). Cognition and learning. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 15-46). New York: Macmillan.

Grundy, S. (1988). *The computer and the classroom: critical perspectives.* Paper presented at the Educational research: Indigenous or exotic? Annual Conference of the AARE., Armidale, NSW.

Hembree, R. (1992). Experiments and relational studies in problem solving: a meta-analysis. *Journal for Research in Mathematics Education, 23*(3), 242-273.

Henderson-Lancett, L., & Boesen, J. (1986). Dragon World 1: implementing an adventure game. In A. D. Salvas & C. Dowling (Eds.), *Computers in education: The crest of a wave* (pp. 115-117).

Heron, J. (1987). Dread Dragon Droom. *Classroom Computing, 7*(1), 15-23.

Larkin, J. H. (1985). Understanding, problem representations, and skill in Physics. In S. F. Chipman, J. W. Segal & R. Glaser (Eds.), *Research and open questions* (Vol. 2).

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge, N.Y.: Cambridge University Press.

Lawson, M. J., & Rice, D. N. (1987). Thinking aloud: analysing students' mathematics performance. *School Psychology International, 8*(4), 233-244.

Mayer, R. E. (1992). *Thinking, problem solving, cognition* (2nd ed.). New York: W H Freeman.

Mayer, R. E., & Wittrock, M. C. (1996). Problem-solving transfer. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 47-62). New York: Macmillan.

McArdle, E. (1985). Adventure games in the classroom. *Com 3, 11*(3), 13-14.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs: Prentice Hall.

Paris, S. G., Wixson, K. K., & Palincsar, A. S. (1986). Instructional approaches to reading comprehension. In E. Rothkopf (Ed.), *Review of research in education*. Washington, D.C.: American Educational Research Association.

Prawat, R. S. (1989). Promoting access to knowledge, strategy, and disposition in students: a research synthesis. *Review of Education, 59*(1), 1-41.

Rhodes, J. (1986). Adventure games in the classroom: a case study. In B. Rasmussen (Ed.), *The information edge: The future for educational computing* (pp. 111-116).

Rice, S. (1985). Adventure games - computers and language. *Classroom Computing, 4*(3), 10.

Ross, B. H., Ryan, W. J., & Tenpenny, P. L. (1989). The access of relevant information for solving problems. *Memory and Cognition, 17*(5), 639-651.

Schneider, W. (1987). *The knowledge base and memory performance: a comparison of academically successful learners*.

Schneider, W. (1990, April 16-20). *Domain specific knowledge and cognitive performance.* Paper presented at the Annual Meeting of the American Educational Research Association, Boston, MA.

Scribner, S. (1986). Thinking in action: some characteristics of practical thought. In R. J. Sternberg & R. K. Wagner (Eds.), *Practical intelligence. Nature and origins of competence in the everyday world* (pp. 13-30). Cambridge: Cambridge University Press.

Sellin, N. (1987). PLS Path (Version 1.8) [Statistical analysis software]. Hamburg: Sellin, N.

Sherwood, C. (1988, September). *Adventure games. A golden opportunity for young learners. The impact of computers on the learning of young children.* Paper presented at the Golden opportunities: Sixth Australian Computers in Education Conference, Mount Lawley, Perth, WA.

Siegler, R. S. (1990). How content knowledge, strategies, and individual differences interact to produce strategy choices. In W. Schneider & F. E. Weinert (Eds.), *Interactions among aptitudes, strategies, and knowledge in cognitive performance*. New York: Springer-Verlag.

Strack, G. (1985). Expedition to Saqqara. *Classroom Computing, 5*(2), 24-25.

Sweller, J. (1990). On the limited evidence for the effectiveness of teaching general problem-solving strategies. *Journal for Research in Mathematics Education, 21*(5), 411-415.

Sweller, J. (1999). *Instructional design in technical areas. Australian Education Review* (Vol. 43). Camberwell, Vic: ACER Press.

Thompson, D., & Duncan, J. (1988). Using adventures in the classroom. *APCC Newsletter*(October).

Unwin, G. (1983). Adventures in education. *Creative Computing*(October), 149-157.