Schema and strategy in problem-solving

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Abstract

We undertook a study in which we investigated the behaviours of students while they played a computer based adventure game. In our analysis, we sought evidence of the use of a range of strategic behaviours - both general and specific to the domain - and evidence of the influence of students' schemas for the problem domain. We compared novice and experienced players in terms of their use of strategies, their access to schemas for these games, and their performances. We also compared the use of strategies and access to schemas of high- and low-performing students. We found that experienced players had well developed schemas and that they did not make greater use of general strategies than novices. Further, we found that high performers did make use of general strategies, but that schema did not influence performance. We report the results of our study, and compare them with published claims about the use of these games as environments for the development of problem-solving behaviours. We comment on the implications of our work for the use of these games in classrooms; we discuss what we see as a perplexing lack of influence of our schema measures on performance; and we reflect on schema theory.

Introduction

Consideration of the nature of adventure games has resulted in the belief that they are environments in which problem-solving skills can develop and that, because of this, adventure games have application across a range of curriculum areas (Bell and Scott, 1985; McArdle, 1985). 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, 1987), and that adventure games encourage application of metacognitive skill (Henderson-Lancett and Boesen, 1986). Taken together, this final group of assertions supports the view that students become better problem-solvers following exposure to adventure games.

In this study we were interested in exploring the claim for enhanced problem-solving performance. 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 found 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 often 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. 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.

We undertook a study of the problem-solving behaviour of students in a novel adventure game and we sought to provide explanations of the results of that study by reference to a conceptual framework drawn from the extensive literature on problem-solving. In doing that we have identified a set of problems associated with key concepts in schema theory. In this paper we summarise our study and review some of the problems that we have identified in schema theory.

Cognitive perspectives on problem-solving

Problems and problem-solving

A problem occurs when a situation is encountered in which the means of achieving a desired goal is not immediately available. In the terminology of the framework for problem-solving research 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 major influence that the student's store of knowledge has on comprehending the situation, selecting moves, and thereby affecting the outcome (Schneider, 1987; Schneider, 1990).

Expertise, knowledge, and strategy use in problem-solving performance

Chi, Glaser, and Rees (1982) claim 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) argue that domain specific knowledge is of major importance in expert problem-solving. Others also support this view (Schneider, 1990; Larkin, 1985). Sweller (1990) goes further and argues 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 postulates 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, schema knowledge should be strongly associated with success in problem solving.

Other researchers argue that it is necessary to qualify this view of the dominance of prior knowledge as a factor in problem-solving performance. They argue 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 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 (Lawson and Rice, 1989; Charles and Lester, 1984; Hembree, 1992; Bereiter and Scardamalia, 1987; Paris, Wixson, and Palincsar, 1986; Clements, 1990). 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 and Holyoak, 1983; Ross, Ryan, and Tenpenny, 1989).

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 (Chi and VanLehn, 1991; Chi, Hutchinson, and Robin, 1989; Alexander and Judy, 1988; 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.

In this investigation of the effect of adventure game experience on problem solving performance we have sought to include measures of both domain schemas and strategy-use as possible mediators of the effects of experience on performance. Of major interest in our study were the effects of adventure game experience on schematic knowledge about games, on the use of general problem-solving strategies, and the relative effects of schema and strategy use on performance. If experience of adventure games enhances problem-solving skills then that experience should result in superior adventure game performance. Experience in use of adventure games could also affect students' knowledge of adventure games or their use of general problem solving strategies. Either, or both, of those two factors could be responsible for enhanced performance. Performance might also be influenced by students' general ability. Our position on these relationships is summarised in Figure 1.

Figure 1: A model representing relationships among Verbal Ability, Experience of computers and adventure games, Schema for adventure games, General Strategy Use, and Performance on the test adventure game measured by the extent to which students completed the task.

Method

Subjects

44 students from three metropolitan schools in Adelaide, ranging in age from 12 to 15 years, participated in the study. Data from four students were lost due to equipment failure, leaving complete data for 40 subjects, of whom 18 were female.

Procedure

Prior knowledge

To assess the extent of previous exposure to adventure games, students completed a questionnaire in which they were asked about their experience of, and affect for, computers, and the number of adventure games that they had played. The questionnaire also sought information on students' age, sex, and knowledge of meanings for 20 words that were taken from the adventure game. Students also completed a standard word knowledge test (Australian Council for Educational Research, 1989) to provide an estimate of general verbal ability. In order to generate information about students' prior knowledge of adventure games, the questionnaire 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, and then to select the move that they thought would be the best one. This list of likely moves and the suggested best move were used to establish a measure of schematic knowledge for adventure games. 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 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 provides an index of performance in the game. The program includes data collection code. As the player made a move, the time of the move, the player's location, and the command issued were recorded in a file.

Think-aloud protocol generation training

Prior to the adventure game session, students were given training in the generation of a concurrent think-aloud protocol. In the training, which used another adventure game, the researcher modelled the 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.

Adventure game data collection

	Planning		Monitoring
P1	Single moves with no forward planning.	M1	Recall that a location has been seen before.
P2	A planned sequence of moves.	M2	Acknowledgment of a memory limitation.
P3	An adventure specific move like	M3	Acknowledgment that an error has

	saving game status.		been made.
	Recognition	M4	Summary reflection on performance.
R	Recognition of the significance of an object.		Errors
	Inference	E1	Error in reading text from screen.
I1	Infers use for an object when it is first encountered.	E2	Error in recall of a location.
I2	Infers use for an object when prompted by a situation.	E3	Error in using a direction. Says East but moves West.

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

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 transcriptions were analysed for evidence of students' use of a variety of strategies, including game specific strategies like 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.

Results

Performances of novice and experienced players

To compare the performances of novice and experienced players, students were categorised as being either novices, having played none, one or two adventure games, as intermediate, having played three or four games, or as experienced players who had used five or more adventure games. The number of objects collected during play and the number of different locations found were combined by summing standard scores on these two measures to produce an index of performance. A t test was used to compare the mean performances of the novice and experienced groups. This analysis (see Table 2) suggests that experienced players outperform novices.

Variable	Novice Mean (SD) N=9	Experienced Mean (SD) N=11	Difference	t	df	p
Performance index	-0.772 (1.517)	0.686 (1.672)	1.458	-2.04	17.77	0.056

Table 2: t-test to compare performances of novice and experienced users of computer adventure games.

The influence of experience on the development of schema

We investigated the emergence of adventure game schema as a function of experience. Operationalising the concept of schema is not a trivial matter, as there are many constructions of this concept in the literature (see Alexander, Schallert, and Hare, 1991). Initially, we developed two schema measures, based on the number of moves that students could generate and their choice of an optimum move for the adventure scenario presented as part of the adventure game questionnaire. These measures were based on Neisser's (1976) definition of a schema, but we were concerned that they did not tap all aspects of schema. Drescher (1991) defines a schema as including sets of apprehended conditions, possible actions, and expected results. In our coding of students' strategic behaviours, we identified adventure game specific strategies, like choosing to save the game when danger threatened. Such strategic behaviours should be seen as a condition-action rule and therefore part of students' schemas for adventure games. Similarly, students' knowledge for adventure game words, allowing for general verbal ability, might also be seen as a measure of the declarative knowledge component of their adventure game schemas. These measures of schema for novice and experienced players were compared using t tests. The results of these analyses, presented in Table 3, show that experienced players are able to generate a greater range of possible moves and are able to select better moves than the novice players, but the groups do not differ significantly on either their use of game specific strategies nor on their knowledge of adventure game words.

Variable	Novice:	Experienc	Differe	t	df	p

	Mean, (SD), N=9	ed: Mean, (SD), N=11	nce			
Number of moves	1.000 (0.707)	1.823 (0.613)	-0.823	-2.79	18	0.012
Proposed Action	1.889 (0.928)	3.769 (1.337)	-1.880	-3.57	18	0.002
Game specific strategies	1.382 (3.574)	2.749 (3.130)	-1.367	0.91	18	0.374
Game word knowledge	-1.367 (3.665)	1.931 (4.936)	-1.575	-0.79	18	0.438

Table 3: t-tests to compare schema development of novice and experienced users of computer adventure games.

In the comparison of novice and experienced players, we can see that experienced players tend to out-perform novices and that they are able to generate more possible moves and to select better moves when presented with an adventure game scenario.

Experience and strategy use

Variable	Novice: Mean, (SD), N=9	Experienced: Mean, (SD), N=11	Difference	t	df	p
Unplanned moves	82.050 (11.566)	72.134 (16.716)	9.916	1.51	18	0.149
Planned moves	3.034 (3.150)	5.996 (8.737)	-2.961	-0.96	18	0.348
Forward inference	0.416 (0.743)	1.180 (1.660)	-0.764	-1.28	18	0.218
Prompted inference	0.679 (1.206)	0.696 (1.242)	-0.017	-0.03	18	0.976
Recognise import	0.693 (1.275)	5.381 (7.995)	-4.688	-1.73	18	0.100
Recall location	8.522 (6.546)	8.598 (7.352)	-0.075	-0.02	18	0.981
Memory limitation	0.654 (0.716)	0.083 (0.277)	0.570	2.44	18	0.025

Notice an error	0.889 (0.670)	0.923 (1.382)	-0.034	-0.07	18	0.946
Reflect on progress	0.111 (0.333)	0.143 (0.475)	-0.032	-0.17	18	0.866

Table 4: t-tests to compare general strategy use of novice and experienced users of computer adventure games.

To investigate whether experience of adventure games promotes greater use of general problem-solving strategies, the experienced and novice groups were compared on the measures of general strategy use derived from transcripts of students' verbal protocols. These comparisons used the t test procedure and the data are shown in Table 4. The only general strategy variable on which there is a significant difference is the recognition that the student has a problem with memory. Here, novices show a higher frequency of this event than experienced subjects. Rather than interpret this as evidence of greater strategy use by novices, it is regarded as an indication that novices do indeed have greater problems in recalling details of the game situation. It is likely that more experienced students, who have more developed schemas for adventure games, are better able to encode information than novices, and therefore do not experience the same level of memory limitation. In other respects, it seems that experience of adventure games does not result in increased use of those general problem-solving strategies that were recorded in this study.

In summary, experienced players of computer based adventure games tend to out-perform novices. They also have better developed schemas for adventure games, but they do not make more use of general problem-solving strategies during their play.

Differences in schema between low- and high- performers

To examine the effects of schema and strategy use on adventure game performance, students were classified as being either high performers (the top quartile) or low performers (the bottom quartile) on a composite measure of performance. The basic measure of performance was the number of objects collected, but it is likely that good performers will also visit a greater number of locations during their attempts at the game. Standardised scores on the two measures, the number of objects collected and the number of different locations visited, were summed to give an index of performance. (In fact, the two variables correlate quite highly with $r=0.848$, $p<0.001$).

The two performance groups were first compared on measures related to adventure game schema knowledge and the results of these comparisons are shown in Table 5.

Variable	Low performance: Mean, (SD), N=10	High performance: Mean, (SD), N=10	Difference	t	df	p
Generation of moves	2.800 (1.549)	3.246 (1.405)	-0.446	-0.67	18	0.509
Proposed Action	1.500 (0.850)	1.705 (0.832)	-0.205	-0.55	18	0.592
Game specific strategies	0.576 (0.859)	2.679 (2.721)	-2.103	-2.33	18	0.032
Game word knowledge	-0.189 (4.799)	1.963 (4.526)	-2.125	-1.02	18	0.322

Table 5: t-tests to compare schema measures for low- and high-performers on a novel computer adventure game.

It is noteworthy that the only schema knowledge related item on which there is a difference between low- and high-performers is the game-specific strategy variable.

Differences in strategy use between low- and high- performers

The use of general strategies by low- and high-performers was compared using t tests, the results of which are presented in Table 6. Significant differences occurred in the use of unplanned moves. These moves are typified by utterances like; "I think I'll just move east here." with no expressed reason for the move and no indication of any depth of planning. Low performers make more such moves than do high performers. This is interpreted as representing a lack of strategic processing by the low performers. The other areas of difference lie in the use of inferences and in the recognition of the significance of information presented on screen. These are argued to be examples of the general strategies that are used by good readers who monitor their comprehension of text by making and testing predictions.

Variable	Low	High	Difference	t	df	p

	performers: Mean, (SD), N=10	performers: Mean, (SD), N=10	nce			
Unplanned moves	77.541 (9.414)	59.003 (16.957	18.539	3.02	18	0.007
Planned moves	8.779 (11.224)	(10.946 (9.732)	-2.168	-0.46	18	0.650
Forward inference	0.088 (0.277)	2.234 (2.142)	-2.146	-3.14	18	0.006
Prompted inference	0.302 (0.647)	1.312 (1.141)	-1.010	-2.43	18	0.026
Recognise import	0.502 (1.215)	11.118 (8.947)	-10.615	-3.72	18	0.002
Recall location	7.214 (6.428)	7.545 (8.554)	-0.330	-0.10	18	0.923
Memory limitation	0.343 (0.584)	0.000 (0.000)	0.343	1.86	18	0.080
Notice an error	0.549 (0.619)	1.421 (1.436)	-0.872	-1.76	18	0.095
Reflect on progress	0.000 (0.000)	0.333 (0.576)	-0.333	-1.83	18	0.084

Table 6: t-tests to compare general strategy use of low- and high -performers on a novel computer adventure game.

High performers do not have significantly better developed knowledge schemas for adventure games. They are however more strategic, making greater use than low performers of both general strategies and of game specific strategies.

Summary of results

We find that experience of adventure games is associated with the possession of better developed schemas. However, despite an association between experience and performance, we find no significant association between schema and performance (see Figure 2 and Table 7). High performance is however related to the use of both general and game specific strategies, but general strategy use is not linked to experience of adventure games. In order to further examine the relationships among the set of variables we developed a path model, shown in Figure 1, and testing it using partial least squares path analysis

with the program PLS Path (Sellin, 1987).
Path analysis enables the model that we proposed (see Figure 1) to be tested against the data that were gathered. This technique yields estimates of the strengths of the contributions of the observed variables to the constructs of our model, and it provides information on the extent of associations, both direct and indirect, among the major constructs that were investigated. The results of this analysis are summarised in Figure 2, and are shown in Table 7. The path analysis reveals a relationship between schema and general strategy use. This is interpreted to mean that having a schema for adventure games reduces the cognitive load of dealing with the information that needs to be stored, possibly by providing an efficient encoding mechanism, and frees the student to allocate cognitive resources to strategic activity.

Figure 2: Results of a path analysis on the model presented in Figure 1. The numbers shown are the direct path coefficients between latent variables.

The reduced path coefficients shown in Table 7 indicate that although there is no direct influence of experience on strategy use, there is an indirect effect through schema. Similarly, although schema does not influence performance directly, it does operate through general strategy use.

	Verbal ability	Experience	Schema	General strategy use	Performance
Verbal ability	100	-	-	-	-
Experience	0	100	-	-	-
Schema	25	51	100	-	-
General strategy use	36	20	39	100	-
Performance	36	31	18	47	100
Squared multiple correlat	-	-	0.34	0.28	0.41

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Table 7: Reduced path coefficients and squared multiple correlations for latent variables from path analysis. These values represent the total effect of one latent variable on another allowing for multiple paths between them.

Conclusion

The influence of adventure game experience on performance

We set out to test claims that experience of adventure games leads to the development of general problem solving skills. From the literature on problem-solving we identified two possible factors, schema and strategy use, that could influence problem-solving performance. We sought evidence for effects of adventure game experience on both schema and on strategy use, and we scrutinised our data for evidence of their influence on performance.

We found evidence for an indirect effect of adventure game experience on problem-solving performance. There is no direct relationship between experience of adventure games and the use of general problem-solving strategies in a novel adventure game. However, experienced players do have better developed schemas for these games and, perhaps through more efficient encoding of information presented to them, experienced players are able to devote more cognitive resources to the use of general strategies. It is the use of these general strategies that is most significant in determining performance.

In comparing the influence of schema and general strategy use on performance, we find that general strategy use has a strong effect and that schema has no direct effect on performance. However, we believe that there is evidence for an interaction in which schema does contribute to performance, but that it does so through an enabling mediation of general strategies described above. This finding is at odds with authors, like Sweller (1989), who have argued for the dominance of schema as an explanatory factor in performance, but is consistent with the position adopted by Siegler who seeks 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

It could be that the students who participated in this study, even the most experienced, have incomplete schemas. They may be at a stage of building a propositional network where they can recognise and encode situations, but not yet at a stage where a set of

conditions is strongly associated with a set of actions and expected results. This explanation is plausible, since the students in this study had received no formal instruction in the use of adventure games. Those students who had played these games had, no doubt, interacted with peers as they worked out what to do. Having had no instruction, their use of strategies, either to act or to reflect on or use knowledge that they had, is entirely spontaneous. In research on students' performance on task analogues, Gick and Holyoak (1983) found that most subjects did not spontaneously use relevant and available information and strategies, but were able to use it if prompted. It may be the case here that prompting or reminding by a teacher would enable students to make more effective use of their schemas directly in reaching a solution. However, the results obtained here do not provide support for the view that more experience with adventure games will result in the development of general problem solving skills. The experienced adventure game players in this study did develop more detailed game knowledge schemas but did not show more frequent use of general problem solving strategies than did their less experienced peers.

We suggest therefore that allowing students to use programs like adventure games in unstructured settings will not directly lead to the development and use of general problem solving strategies, even though such skills are important contributors to performance in this domain. If such games are to be effective in increasing these skills, it will be especially important for the program designers and teachers to provide guidance on how the programs can be used, and what strategies are likely to be effective for encoding and using the information presented in the game.

Discussion

We need to discriminate between questions about what constitutes expertise and questions about how novices become expert. We need to know whether experts use highly developed schemas to apprehend, classify, and solve problems or whether they are very good at using more general strategies to solve those problems. In this context we need to know what schemas are and from that to develop measures of schema. Once we can nail down a workable definition of schema, we can begin to investigate later questions about the processes by which novices might develop expertise. Answers to these questions will inform instruction.

Schema theories abound and evolve (Minsky, 1975; Gentner and Rumelhart and Ortony, 1977; Rumelhart, 1980; Stevens, 1983; Rumelhart, Smolensky, McClelland, and Hinton, 1986; Rumelhart, 1989). Gardner asserts that:

> To my mind, the major accomplishment of cognitive science has been the clear demonstration of the validity of positing a level of mental representation: a set of constructs that can be invoked for the explanation of cognitive phenomena, ranging from visual perception to story comprehension. ...schemas, images, rules, transformations, and other mental structures and operations, ... are now taken for granted and permeate the cognitive sciences.î
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> Gardner, 1987 p. 383

Alba and Hasher (1983) question the research basis for the parsimony of current schema theories. They accept that there are basic processes involved in schema development - selection, abstraction, interpretation, and integration - but that they involve a much richer memory trace than has been posited by frame and script schema theories. If Alba and Hasher are correct in their view, much more detailed measures of schema must be available than those that we have used in this study.

An approach to understanding the first issue - what a schema is - might be found in the second set of questions that we have sought to raise: How is a novice transformed into an expert? Novices can be presumed not to have a schema for a given domain. They must only have recourse to a general set of strategies which must fulfil the functions of the four basic schema processes identified by Alba and Hasher. Such processes must enable the individual to attend to (select) particular aspects of the situation. Having attended to those aspects, a judgement must be made about the value of the outcome that resulted from the selected stimulus. The sum of a number of such judgements will inform the individual about the relative importance of the range of elements of the problem situation. The importance criterion can then be applied in the selection of future stimuli for attention. The implication of this is that a common set of basic processes are involved both in novice problem-solving and in schema induction and modification.

For a relative novice to solve a problem, analogous processes to those identified by Drescher - mechanisms for recognition of a problem condition, access to possible actions, and an expectation of certain results - must be available. Drescher offers an explanation of how such general processes become specialised through experience in a domain, and become the relatively automated condition-action rules that drive expert problem- solving. Thus, rather than constructing novice - expert studies as being comparisons of groups with quite different attributes - general strategies versus a well conditioned schema - the differences might be the degree of specialisation of the same basic set of processes, albeit in the latter case, acting on a better developed knowledge base.

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