Title	Problem-solving behaviour of O-level geography students: Some exploratory findings
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Source	*ERA Conference, Singapore, 24-26 September 1992*
Organised by	Educational Research Association of Singapore (ERAS)

PROBLEM-SOLVING BEHAVIOUR OF O-LEVEL GEOGRAPHY STUDENTS: SOME EXPLORATORY FINDINGS

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INTRODUCTION

There is much interest in Singapore in enhancing the thinking, reasoning and problem-solving skills of students. DeBono's CoRT thinking skills programme, for example, is now in use in Singapore schools. Attempts to integrate such content-free thinking skills programme into various curriculum subjects are being encouraged. At the same time, there is inadequate research in examining how students actually think in a content area. This study is an exploratory investigation in examining how students, in particular, "O" level geography students, actually think when they are solving a problem.

Both domain-general reasoning ability and domain-specific knowledge have significant roles in reasoning and problem solving (Dewey, 1939; Lee, 1992; Sternberg, 1989). In order to reason very deeply about any subject, one has to have more than a superficial knowledge about that subject. However, the amount of knowledge one has is a necessary but insufficient prerequisite to its use (Whitehead, 1929). More important perhaps is the way that knowledge is organised. An organised knowledge base will, according to some researchers, facilitate the use of that knowledge in problem solving (Chi, Feltovich & Glaser, 1981; Glaser, 1984). In exploring how students actually think in solving a problem, this study attempts to find out whether or not there are qualitative differences in the way students of varying general reasoning ability and knowledge structures solve a geographical problem.

THEORETICAL FRAMEWORK

The information-processing framework is currently the dominant theoretical paradigm in the area of reasoning and problem solving. The paradigm was initially developed by Newell and Simon (1972) in the context of well-structured problems like puzzles or arithmetic problems. Voss et al. (1983a) used the general information-processing paradigm as a framework to develop a more specific model of the problem-solving process in the social sciences.

According to Voss et al. (1983a), a typical way to solve a social science problem is to isolate the cause(s) of the problem. The causes of the problem are viewed as factors that play a role in producing the problem, and these are taken to be subproblems and/or constraints. Voss et al. (1983a) distinguishes subproblems and constraints in the following way:

> Subproblems are typically regarded as problems that are subordinate to a more general problem. Constraints on the other hand are usually regarded as factors assumed to be invariant over the course of solving of a particular problem that in some way restrict the range of solutions (p 170).

The distinction of subproblems and constraints in the social appears to be less definite. A factor that is identified early in the solution process as a constraint may later become a subproblem if the problem-solver attempts to provide a solution to that subproblems. In many social science problems, the subproblems and constraints are not provided. Thus, the problem-solver must rely on personal knowledge of the domain to identify them.

Once the problem-solver has isolated the cause(s) of the problem, a solution may be sought. After proposing a solution, the problem-solver may first, provide support for the proposed solution, second, isolate subproblems that need to be solved in order to implement the proposed solution, and third, evaluate any of the solutions. All these activities may be undertaken during the evaluation phase of the problem-solving process. The evaluation phase, therefore, involves the development of argument as the problem-solver tries to build a case for a proposed solution.

This study uses the phases outlined in this model of problem solving as a framework to examine qualitative differences in the way geography students of varying general reasoning ability and knowledge structures solve a problem.

METHOD

The O-level geography students (n = 24) were randomly sampled from four different groups: students with high ratings in both general reasoning ability and knowledge structures (HH), students with high ratings in general reasoning ability but low ratings in knowledge structures (HL), students with low ratings in general reasoning ability but high ratings in knowledge structures (LH), and students with low ratings in both general reasoning ability and knowledge structures (LL). Students' general reasoning ability was measured by the Thorndike-Hagen Cognitive Abilities Test (CogAT), Form 4, Level G and their knowledge structures were measured by the Concept Structure Analysis Task (ConSAT; Champagne et al. 1981). Figure 1 shows the sample of students interviewed in each of the four groups.

Figure 1 Distribution of students in the four groups

GENERAL REASONING ABILITY	KNOWLEDGE STRUCTURES: High	KNOWLEDGE STRUCTURES: Low
High	9 (5 gifted 4 nongifted)	6 (2 gifted 4 nongifted)
Low	4 (4 nongifted)	5 (5 nongifted)

These 24 students were asked to think aloud as they solved a geographical problem entitled, "The Squatter Problem in Bombay". The problem statement involved a description of the squatter problem in Bombay as a result of rapid and unplanned urban growth. Several subproblems associated with the squatters in Bombay were provided in the problem statement. These included the poor quality of dwellings, overcrowding, availability of limited services, and unemployment. The students had to put themselves in the shoes of city authorities committee members responsible for alleviating the squatter problem in Bombay. Their task was to generate proposals to the World Bank which is considering aid to the city.

Students were given time to read the problem statement and to clarify with the researcher any terms they might not have understood in the problem statement. Once they understood the problem, they were then encouraged to think aloud while generating a solution, being encouraged to state

whatever ideas that came to mind as they tried to solved the problem. These verbalizations were tape-recorded and transcribed.

DATA ANALYSIS

Two approaches were used in analyzing the think-aloud protocols generated by the four groups of students. First, protocols in each of the groups were examined for a common pattern that was characteristic of the group's approach to problem solving. Second, comparisons among groups were examined in order to highlight qualitative differences among them. The problem-solving and reasoning model developed by Voss et al. (1983a) was used as a tool for analyzing the think-aloud protocols. The model consists of a problem-solving control structure (G) and a reasoning structure (R). The G operators are shown in Figure 2.

Figure 2 Problem-Solving Control Structure Operators

GCON	State Constraint: When a solver explicity or implicity indicates a problem constraint.
GSUB	State subproblem: When the solver indicates that a particular factor is being used as a subproblem.
GSOL	State solution: When the solver states a solution, either to the given or to a subproblem, explicity or implicity expressed.
GIPS	Interpret problem statement: When the solver considers how the problem is to be interpreted.
GSUP	Provide support: When the solver is using some type of argument to support the existence of a sub-problem or constraint.
GEVA	Evaluate: When the solver develops an argument that supports or rejects a solution and when the solver evaluates a solution in relation to a particular constraint.
GSUM	Summarize: When the solver presents a summary of a relatively large portion of the protocol.

The first three operators, State Constraint (GCON), State Subproblem (GSUB) and State Solution (GSOL) constitute the hard-core operators, which in one form or another may be found in most descriptions of problem-solving. The remaining four operators, Interpret Problem Statement (GIPS), Provide Support (GSUP), Evaluate (GEVA) and Summarize (GSUM), are supportive to the first three operators. They are used in conjunction with reasoning structure operators as in Fig. 3.

The protocols of each student were initially divided into ideas units. In most cases, a unit was a sentence, but on occasion it was a clause or a number of sentences. The inter-rater reliability of segmenting the idea units within the protocols was .97. In analyzing the protocols, every effort was made to stay as close as possible to the protocol contents.

Figure 3 Reasoning Structure Operators

RARG	Statement Argument: When an argument is made by the solver.
RSAS	State Assertion: When the solver refers to a constraint, subproblem or solution, but the factors referred to are not in the goal structure of the solution process.
RFAC	State Fact: When the solver supports another statement via the statement of a fact.
RPSC	Present Specific Case: When stating a specific case or example which demonstrates the contents of a previous statement.
RREA	State Reason: When the individual states a reason for a previous statement.
ROUT	State Outcome: When the solver states an outcome of a person's statement.
RCOM	Compare/Contrast: When the solver compares a previous statement with some other entity related to the statement.
RELA	Elaborate and/or Clarify: When the solver attempts to elaborate or clarify a previous statement while essentially not adding anything new.
RCON	State Conclusion: When a concluding statement is provided after a series of previous statements.
RQUA	State Qualification: When the use of a statement restricts the range of application of the previous statement.

RESEARCH FINDINGS

Qualitative analyses of the think-aloud problem-solving protocols of the four groups of students resulted in the following findings:

1. A common pattern that characterized HH and LL groups' approach to problem solving emerged from the data but there was no clear pattern that characterized HL and LH groups' approach to problem solving. Some HL and LH students solved the problem in a way that resembled HH students. Others behaved more like LL students.

2. As a whole, these students spent less time on problem analysis but more time on problem solution.

3. There was limited argument development in the protocols of the students, even among the gifted students. While argument development in the protocols of the students was quite limited, the gifted students from the HH group made stronger arguments than students from the LL, HL, and LH groups. The only exception was student LH1 who had quite an extensive argument development in her protocol.

The variability that exists among students in the HL and LH groups made between-group comparisons difficult. However, it was possible to draw some general observations regarding differences between the HH and LL groups. First, HH students spent a little more time in analyzing the problem than the LL students. They explored fundamental causes of the squatter problem, such as rural-urban migration and population increase, prior to a discussion of the solutions to the problem. On the other hand, LL students went straight into a discussion of the solutions to the problem and paid little attention to examining the problem.

Second, the HH students attempted to decompose the general squatter problem into smaller subproblems but this strategy of problem decomposition was noticeably absent in the LL students. The strategy of problem decomposition used by the HH students took the form of a listing of subproblems, for example:

> First we examine the problem. Number 1 there is unplanned growth. Number 2, we have poor housing that is sort of poor materials. Then we have overcrowding and there are too many people for the limited services ... right. And there is also unemployment. Now we have proposals to improve the conditions. So we should tackle them one by one.

Most of the subproblems listed by the students were also similar to the ones provided in the problem statement. Some HH students did not list the subproblems in their problem-solving process, but the solutions they suggested implied that they had certain subproblems in mind. On the other hand, LL students made little attempt to decompose the problem into smaller subproblems, for example:

> Basically from what I think ... how to solve the problem is to extend the urbanisation rate, that is, urbanised the area further up so that when you urbanised the area, the government authorities will drive away the squatter and most of them will be pushed rather back into the country. Providing jobs is another alternative for them ... this is basically, are the two ways to solve it.

Third, the HH students provided a wider range of solutions than the LL students. The solutions they suggested were also more abstract. For example, one student suggested the development of another urban area to be located relatively near to Bombay so that the population could live there and commute to Bombay to work. Another suggested rural development as a means of reducing rural-urban migration which is a major cause of the squatter problem. The LL students generated fewer solutions. The solutions they provided were not as abstract and were meant to solve low-level subproblems. These included solutions such as the provision of jobs to solve the problem of unemployment among squatters, and the clearing of slums to solve the poor housing conditions.

Fourth, there was more argument development and reasoning in the protocols of the HH students than the LL students. These HH students provided an evaluation of the solutions they suggested. In evaluating these solutions, the implications and constraints of some of these solutions were considered. HH students realised the complexity of the squatter problem and they had great difficulty coming to a decision about a final choice among alternative solutions. They offered a package of solutions as a general solution to the problem rather than a single solution. They also considered the time-frame for solutions to be implemented. The transcript below is an example of an attempt by a HH student to develop an argument for the solutions he suggested.

> These are some of the possible solutions. Now ... we are suppose to choose the proposals that we would suggest to the committee. So we should now reexamine all the possible solutions. Let's see ... solutions. Now let's consider some factors ... money, time taken to implement these things... um ... extent and effect on people's lives ... the effectiveness of the solutions.
>
> What we want here is a long-term solution to this problem. First of all, in order to curb unplanned growth ... we have to have better planning definitely and we must also have better enforcement by the city planners. When we talk about demolishing these existing housing, we need to reexamine as to whether is it really necessary. Maybe not. If we were to demolish everything at one go ... probably for the people

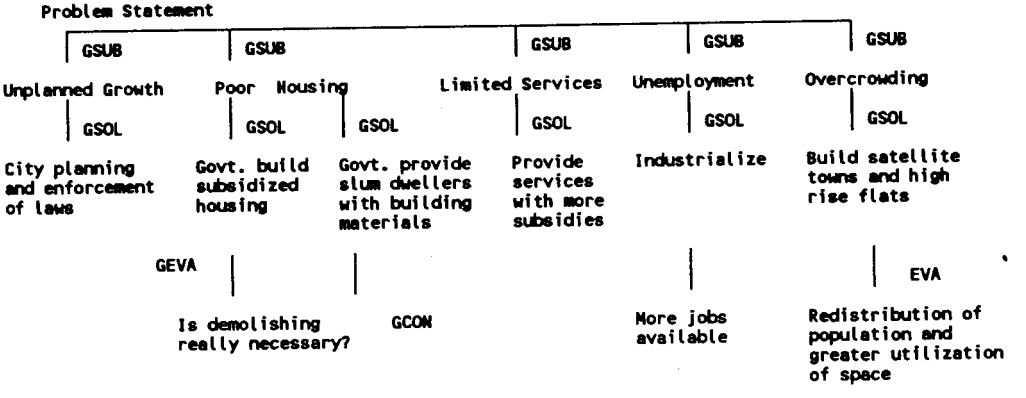
> it might be quite difficult to get the people out and to rehouse them. Possibly the solution to this problem might lie in doing things in several steps. You must remove the people from there. Demolish the existing poor housing and rebuild the place.

In contrast, LL students attempted to evaluate their solutions only after some probing by the researcher, for example:

> the first thing I will select for implementation is to build more high rise buildings if there is financial help from other countries ... So by building, by installing them into high-rise buildings, the problem of shanty areas ... that is, the facilities can be concentrated in one area.

LL students did not evaluate all the solutions but chose to evaluate the solution they wished to implement. In addition, all LL students, with the exception of one, did not mention the time-frame for solutions to be implemented. Figures 4 and 5 show the problem-solving control structure of a HH student and a LL student.

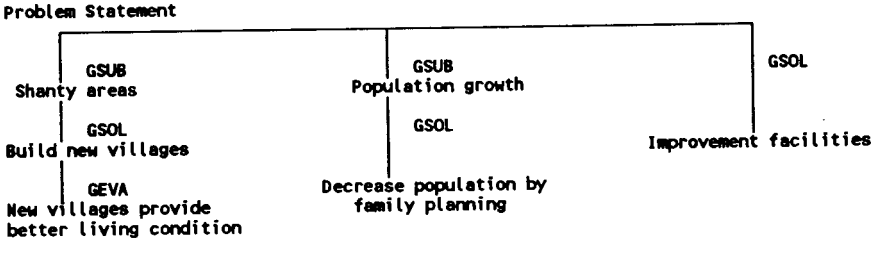
Figure 4 Problem-Solving Control Structure of a HH Student



SAMPLE OF REASONING STRUCTURE (GEVA: EVALUATES A SOLUTION)

RArg We need to examine as to whether it is really ... to demolish existing housing. Maybe not if we were to demolish everything at one go.
RRea It might be quite difficult to get the people out and to rehouse them.
RCon ... the solution ... might be in doing things in several steps.
RElа ... You must remove the people from there ... Demolish the existing prior housing and then rebuild the place.

Figure 5 Problem-Solving Control Structure of a LL Student



SAMPLE OF REASONING STRUCTURE (GEVA: EVALUATE A SOLUTION)

RArg	First, I would develop ... plan illegal settlers into a new village.
RRea	because it is a terrible sight.
RSas	normally these people are very unhygienic.
RSas	So if I am to place them in a popular area,
ROut	they will live in that hygienic condition, a better condition than before.
RCon	The best thing to do
RRea	because they can be a problem to the country
RExa	because these people are normally uneducated so they can create problems.

DISCUSSION OF FINDINGS

It is useful to compare the performance of the geography students in this study with the performance of experts solving social science problems. A model of experts solving social science problems has evolved from the research of Voss and his colleagues in the domain of political science (Voss, Tyler & Yengo, 1983b). The solving of social science problems, according to them, involves distinguishing between the development of the problem representation and the subsequent solution process. Experts spend a relatively large proportion of problem-solving activity in developing a representation of the problem. They delineate the constraints of the problem and subsequently, develop an orientation to it. The problem orientation typically involves a statement that the problem is political, technological, social, or of some other type. The classification of the problem in terms of its orientation provides the expert with the problem representation from which the solution process may proceed.

Once the representation is developed, the expert problem-solver proposes a solution. The solution proposed by an expert is usually abstract. Generally, experts offer only one or a few abstract solutions. The expert problem-solver, spends much of the subsequent solution activity in justifying and examining the solution that was proposed.

Social science problem solving also involves the development of a series of arguments. Argument development for the expert can be seen to achieve several purposes. First, it is simply to justify a solution to show that it is a good solution to the problem and that it can be achieved. Second, it is to examine possible problems arising from the proposed solution and to determine how those, in turn, might be solved. Third, it is to evaluate the solution in the light of the problem representation. Fourth, it is to elaborate or to state the proposed solution more clearly. Fifth, argument development may aid in the retrieval of new information which may then suggest even more solutions.

How did the geography students in this study perform when compared to the picture of experts drawn by the work of Voss and his colleagues? The HH students behaved more like the experts in their problem-solving behaviour. They showed more reasoning and argument development in their protocols, but these were not so extensive as those of the experts'. The LL students behaved more like novices in their problem-solving behaviour. They behaved very much like the novices in a study on expert and novice software designers (Jeffries et al., 1981). In that study, it was found that novices not only failed to apply problem decomposition as a strategy in problem solving, but they also provided little generation and evaluation of alternative solutions to the problem. There was a wide variability among HL and LH students in their problem-solving behaviour. In some cases, the HL and LH students behaved more like the experts but in other cases, they behaved very much like novices.

CONCLUSION

While one does not expect the performance of these students, especially the LL students, to resemble exactly the experts who have had more years of experience in the domain, a question that is relevant for schools to consider is how we can help these students move closer in a continuum

towards the performance of experts. It is possible for students to acquire some of the strategies and knowledge that they are lacking so that they will perform more competently in the decision-making task (Gagne, 1980). Underlying this point of view is the belief that environmental factors, including instruction, can make some significant difference in subsequent abilities to learn and reason. A real challenge for geography teachers in Singapore is to find practical ways of helping students, to perform more competently in a problem-solving task.

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