AD-A154 971 POINTS OF VIEW IN PROBLEM SOLVING AND LEARNING: INTERACTIVE MICROWORLDS F..(U) CALIFORNIA UNIV SAN DIEGO LA JOLLA INTERACTIVE TECHNOLOGY LAB.. 1/1

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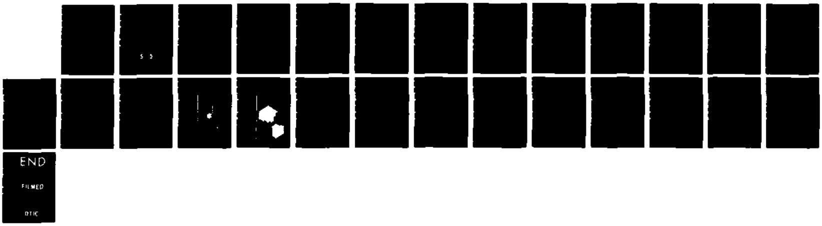

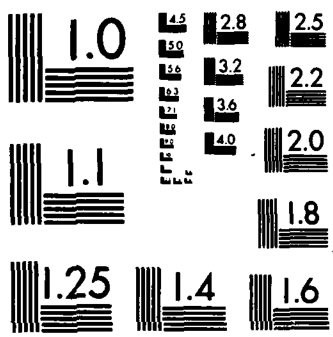

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Points of View in Problem Solving and Learning:

Interactive Microworlds for Instruction

Final Report

ONR Project #N00014-84-K-0107

December 1, 1983-March 14, 1985

Interactive Technology Laboratory

University of California, San Diego

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Abstract

This project conducted studies of the role that conceptual point of view plays in problem solving, especially when a problem solver is blocked. During this project, several graphic microworld for studying point of view were designed and implemented, and several experiments were conducted investigating aspects of conceptual point of view in problem solving. This work has developed a firm base from which to develop computer-based tools for problem solving (especially joint problem solving) and instructional approaches for students to learn flexibility in problem solving.

Introduction

We have been conducting studies of the role that conceptual point of view plays in flexible problem solving. An important goal of our studies is to develop tutorial programs that can be used to teach problem solving flexibility. During the first year, we developed a number of graphic microworlds that will be used both for the experimental studies and as a base for a tutorial system. In our second year of work, we propose to use the graphic microworlds developed during the first year to accomplish two goals:

1) To investigate the role of systematic shifts in conceptual points of view on flexibility in problem solving in a chemistry microworld.

2) To develop these graphic microworld programs into tutorial programs for teaching the use of systematic shifts of conceptual points of view as a metacognitive strategy for increasing flexibility in problem solving

across different problem domains.

Our guiding hypothesis is that an important strategy for overcoming blocks in problem solving is to shift one's point of view on the problem. We plan to conduct experiments that study the role of different conceptual points of view by manipulating the graphic presentations of the task to a subject, by allowing the subject to manipulate the graphic presentations, and by observing pairs of subjects with different presentations of the task.

Theoretical background.

Recent research on the differences between experts and novices have pointed to the importance of having many different ways of thinking about a task. An expert approaches a problem at a "global" level, and then adopts progressively more "local" levels of organization until s/he can solve the problem (Larkin, McDermott, Simon & Simon, 1980). In contrast, a novice, who has only the most specific way of thinking about the problem, gets lost in the morass of details. For example, in physics problem solving, novices start writing down equations, while experts classify the problem and/or draw diagrams before writing down any equation (Chi, Feltovich & Glaser, 1981).

Problem solvers can also differ in the "perspective" they take on a problem. For example, Hutchins & Levin (1981) found that subjects solving a river crossing problem mentally placed themselves in the problem, either on one side of the river or the other. Subjects changed their placement during the course of the problem. This placement, their mental "point of view," affects the kinds of mistakes that solvers make. When subjects placed themselves mentally on one side of the river, they were more likely to make a move that produced an illegal state on the opposite side.

Miyake (1982) also found that subjects who were jointly solving a problem took different points of view in relation to the task. She found subjects varying both their perspective of the task and their conceptual distances from the task (and thus their "scale" of resolution). When one of the joint problem solvers became "blocked" on a problem, it was often the interaction with the other solver with a different point of view that generated progress on the task.

Point of view has been found to be important in other areas of human cognitive functioning. Abelson (1975) showed that point of view affected subjects' recall of stories. Subjects tended to remember details highlighted by the point of view assigned to them before hearing a story. Black, Turner & Bower (1979) found that point of view played a significant role in narrative comprehension, memory, and production. Not only did they find that assigned point of view affected recall, but they also found that there are cognitive costs associated with switching points of view.

Piaget (1956) charts the developmental progression of the ability to coordinate actual and imagined points of view at different perspectives in his study of the child's conceptions of space. The very young child assumes falsely that his/her point of view is the <u>only</u> possible point of view. The discovery of the role of point of view, Piaget argues, requires the coordination of <u>all</u> possible points of view. It is through the mental grouping of mental action patterns (which Piaget refers to as concrete operations) that the child coordinates multiple perspectives and places his/her own point of view in a constellation of possible viewpoints.

Piaget's theory did not take into account the finding that the form and content of problems could make formally identical problems appear very different. D'Andrade (1982) showed that college students can apply a formal operational rule when it is cast in terms of a relationship with which they are familiar but do not solve the "same problem" when the rule deals with an unfamiliar relationship. In the concrete form of the problem the subjects are instructed to take the point of view of a store manager checking a store rule about checks and signature authorizations. In the abstract version the rule is presented in terms of relations between letters and numbers. D'Andrade's research and that of Wason & Johnson-Laird (1972) suggests that formal operations may not be equally applied in all domains. Instead, formal means of thinking are domain specific (LCHC, 1982). They only develop in those areas that we have a high interest and some formal training. In the domain of their expertise, experts employ the formal logic that enables them to coordinate all points of view into a format that helps to understand not just a single relationship but all relationships.

It may be that as one enters a new domain, for example chemistry, one goes through a condensed version of the developmental sequence that Piaget charts for the child. Novices at first assume that the point of view that they take in solving a problem is the only logical one. With more knowledge they may be able to construct a set of possible points of views but not create the overall frame that relates the different points of view into a single system. An expert is able to hold in mind a frame which relates different points of view on the problem and yet to explore the different salient dimensions from these different perspectives to find the most efficient solution to the problem.

The issue of point of view arises in most everyday problem solving. Most non-laboratory problem solving involves more than one problem solver. This is especially true of most instructional settings, as our society has systematically evolved institutions that bring learners into interaction with teachers. Given individual diversity, this almost always means that the different problem solvers in interaction bring different points of view to instructional settings. They often consider the same task elements, but place them in different perspective or consider them at different scales of analysis. This difference in point of view can lead to communication difficulties since each person thinks the other is thinking the same way about the problem because they mention the same elements.

This difference in point of view in joint problem solving is also an opportunity when one of the problem solvers gets "blocked". In some cases, a problem solver is blocked because s/he just doesn't know all the elements required to solve a problem. But in other cases, a problem solver knows all the elements, but still can't solve the problem. It is in these more mysterious cases that a different point of view provided by another can help.

From our previous studies of problem solving (Hutchins & Levin, 1981; Miyake, 1982), we have observed "conceptual point of view" varying on at least two different dimensions:

1) Distance: the conceptual distance of the solver from the problem and thus the conceptual "scale" of resolution of the task elements.

2) Perspective: the conceptual "angle" that the solver takes in respect to the problem and thus what parts of the task elements at a given level are emphasized.

Point of view as a theoretical construct draws upon a visual metaphor. The experiments described in this proposal are based on more explicit models of cognitive processing. Our models are constructed within an "activation framework." Concepts are stored in a large network structured long-term memory, only a small part of which is "activated" at any moment in time. Concepts can be more or less "active." If very active, then a concept will have an important impact on the current processing; if it drops in activity sufficiently, then it becomes inactive and has no impact. The degree of activity is called a concept's "salience."

Different points of view on a given problem are represented by the same set of "active concepts" but with different relative saliences. So for example, for a global and a local point of view of the same problem, there would be the same set of active concepts for the elements of the problem. In the global case, the concepts that organized a larger scope of the problem would be more salient, and in the local case, the more micro level concepts would be more salient.

Progress to date

During the first year of our study, we have implemented several graphic microworlds, and are in the process of augmenting and refining these microworlds. We are also conducting several preliminary experiments (using more conventional media) on the role of point of view in problem solving, especially with several problem solvers working jointly.

Brownian Chemistry Microworld

Our first microworld that we developed was a visual representation of chemical reactions. The screen is a two-dimensional view of a chemical solution, with atoms and molecules moving around randomly, bouncing off the walls. The problem solver "rides" any of the components, and steers it with the microcomputer's mouse. When the component is next to some other component, a button push will cause a reaction, and the problem solver then is riding on the resultant. The problem solver can also choose to change to some other component in this world. The goal is to produce some specified compound from the components that start out in this world. This microworld is shown in figure 1.

We will use this microworld to study shifting points of view, both shifting within any one level as the problem solver shifts from one component to another, and also between levels, as the problem solver selects different views of the same set of elements.

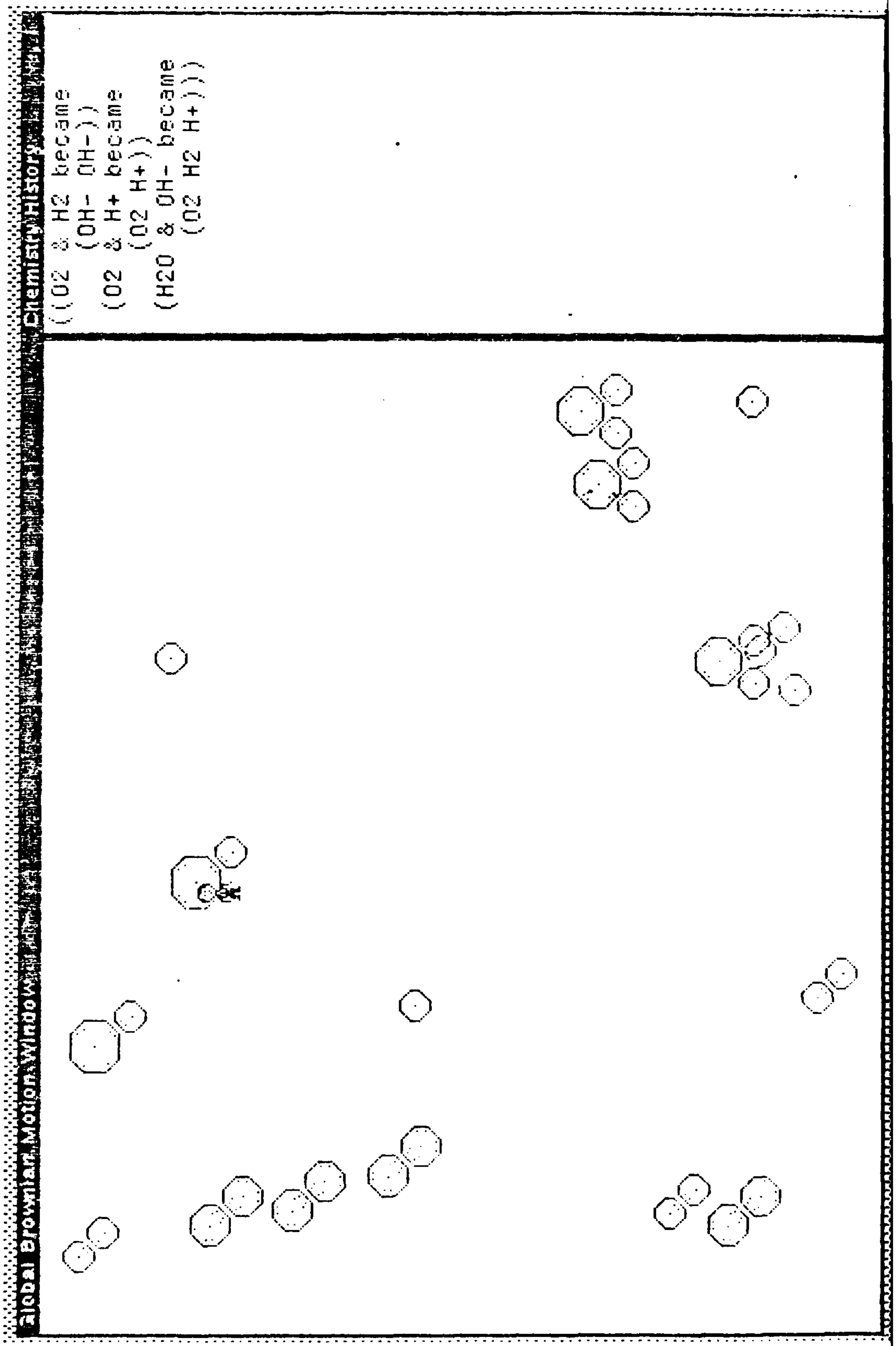

Figure 1: A Brownian Motion Chemistry Microworld

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List of Publications

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to address some of the issues concerning how groups can be effectively coordinated in their problem solving. We will especially focus on how more than one problem solver can best work together when they are blocked in their joint problem solving.

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Ernst, G. W., & Newell, A. (1969). _GPS: A case study in generality and problem solving._ New York: Academic Press.

In this project, we propose to develop a tutorial approach that is based on this concept of dynamic support. The microworlds we develop will train students to be flexible problem solvers in that domain while providing considerable support. Then the students will be able to take over more and more of the task, until they are experts at flexible problem solving. Then they will be trained to apply those same skills in very different task domains, until they have the metacognitive skills to consider applying these same techniques to totally new domains.

In the second year of the project, we will investigate the role of systematic shifts in conceptual points of view on problem solving in the microworlds we developed in the first year. Our second goals will be to evaluate the effectiveness of shifts in points of view as a metacognitive problem-solving strategy. We will develop tutorial systems (based on the microworld systems already developed) to train subjects to vary their points of view in systematic ways. We will test the ability of subjects thus trained to transfer these strategies to different problem domains.

As experiments in the microworlds we have developed are being conducted, we will continue to develop the microworld programs to use the power of their graphic displays to train subjects to apply shifts in their conceptual points of view in blocked situations. We thus plan to develop our microworld programs into tutorial systems for training students to acquire flexibility in problem solving. We will conduct further experiments to evaluate whether this training in fact transfers to other kinds of problem solving, both in the computer microworlds and in other settings.

By using the methodology of joint problem solving, we will also be able to non-computer settings.

Future directions

Much of our educational system is predicated on transfer: the assumption is that skills learned in the instructional setting will transfer to real situations encountered later. However, recent studies (Gick & Holyoak, 1980; Reed, Ernst, & Banerji, 1974) have pointed to the problematic nature of transfer of problem solving expertise. We are interested in discovering ways to train problem solvers to be flexible, so that they can be flexible problem solvers not only in the particular task domain they are trained in, but also in other domains. Our approach to the problem of transfer is based on the concept of "dynamic support".

In our previous research, we developed the concept of "dynamic support" as a way to describe the progression to expertise that we observed (Levin & Kareev, 1980; Levin, Boruta & Vasconcellos, 1983; Riel, 1983; Riel, Levin & Miller-Souviney, 1984). Children learning to use a computer word processor, computer-based writing or mathematics tools, or educational games in afterschool or classroom settings all learned most effectively when they were provided initially with lots of support, then gradually took over more and more of the task as they acquired expertise. This approach contrasts to the usual educational approach of dividing up a task into small atomistic pieces and training a novice on those pieces in a context isolated from the whole task.

In these experiments, different divisions of the task were assigned, with the expertise of the players varied systematically. The results support the importance of point of view for an efficient coordination of joint effort.

What's unique and innovative about this project?

This project is the confluence of strengths, both in cognitive science modeling frameworks, in cognitive psychological expertise in experimentation, and in programming of graphics on state-of-the-art personal computers. Through the chemistry microworlds that we are developing and the synchronization of two Xerox 1108s via an Ethernet, we are able to create a continuum of controlled problem solving situations in which we can study:

- effects of different points of view on problem solving

- the degree of overlap of points of view for the joint problem solvers, and the impact of the differences for mutual understanding and effective communication

- the impact of more than one point of view on a single problem solver (whether upon self-control or experimentally controlled)

Joint problem solving among two or more persons is a situation often encountered in real life. This project will bridge the current gap between laboratory studies and real life situations. We will be explicitly looking at the transfer of flexibility strategies learned in the computer microworlds

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Figure 5; The Air Traffic Controller Simulation Microworld

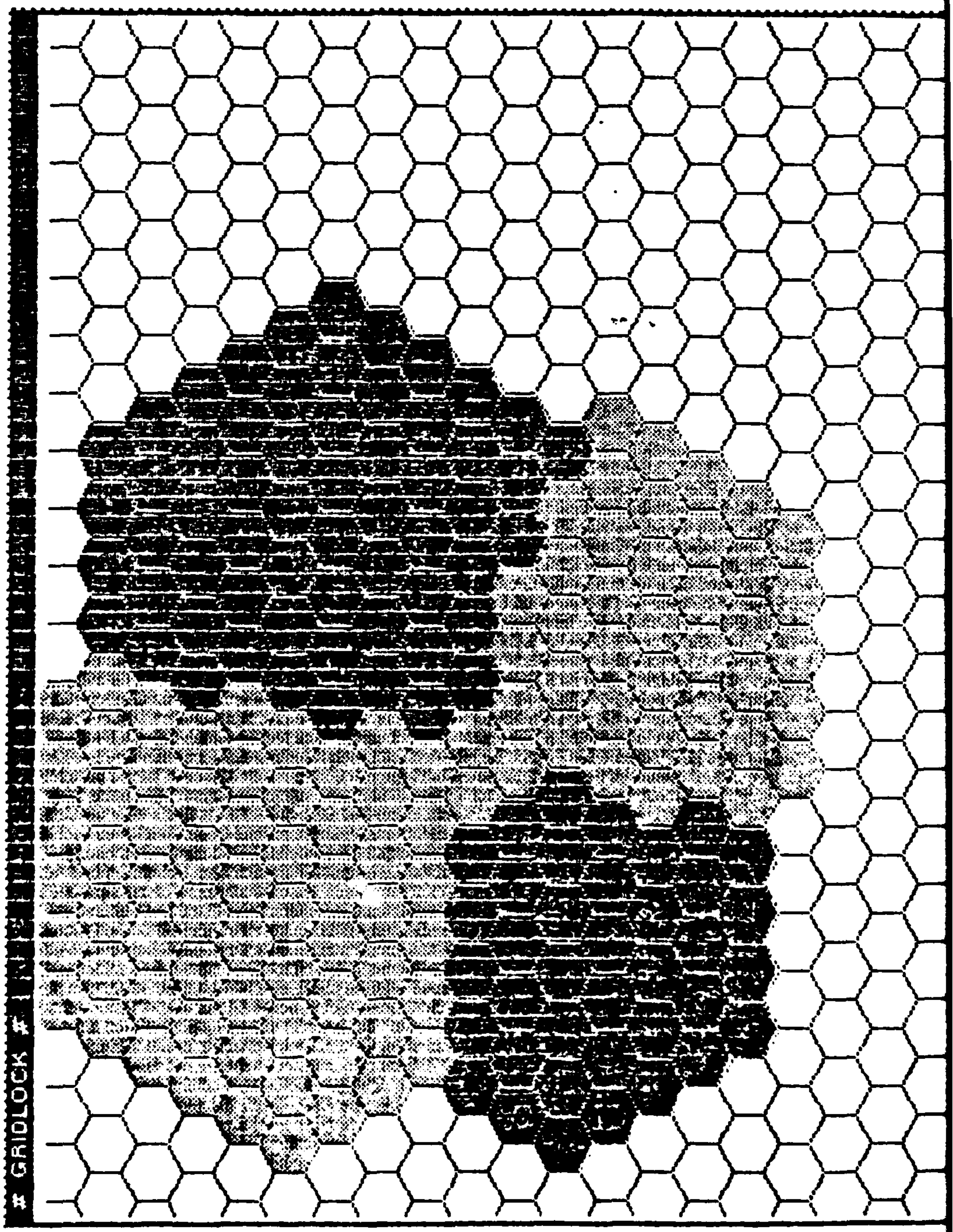

Figure 4: The crystalization microworld at a later time

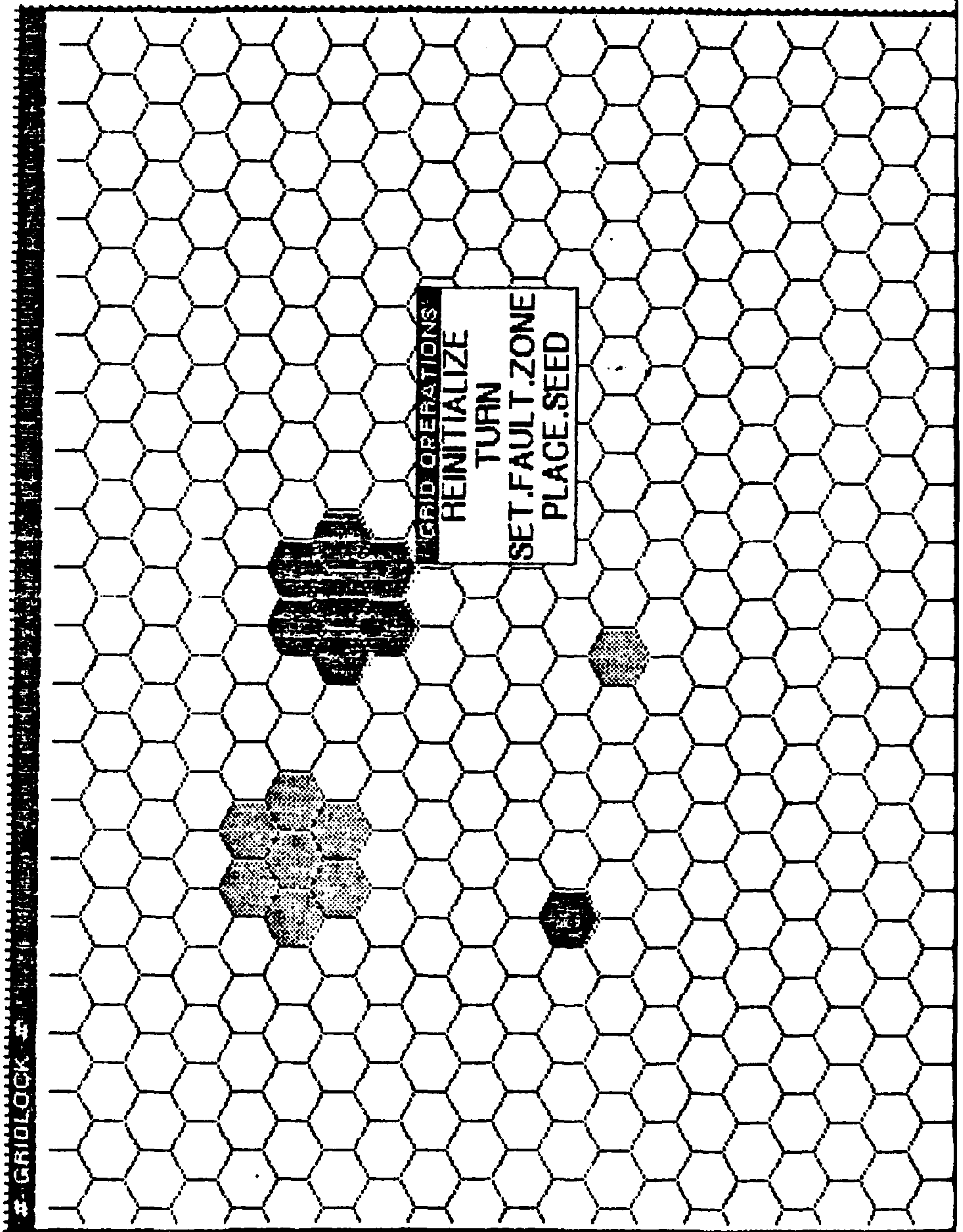

Figure 3: A Crystalization Microworld

the players has to be allocated simultaneously to several different places on the screen. This world is a simulation of crystal growth in an uncrystalized medium, in which the players place "seeds" to initiate growth. Points where the growth patterns collide create "faults", which are opportunities for further growth in this game. This dynamic microworld will be used both for studies of individual problem solving and for joint problem solving. See screen printouts of this microworld in figures 3 and 4. This world will allow us to investigate the effects of shifts of points of view at the same level, and the effects of joint problem solvers, each with a point of view at a different level.

The Air Traffic Controller Simulation Experiments

Miyake, Levin, and Black (1985) conducted a series of experiments investigating the role of point of view in problem solving in a simulated world called "Air Traffic Controller". This is a commercially available microcomputer-based game which simulates the task faced by air traffic controllers. The player is shown a display which represents a "computer-assisted radar display" of an area 15 x 25 miles, from ground level to 5,000 feet altitude. (See figure 5.) Within this area there are two airports (denoted as # and %), and two navigational aids (each marked by a *), and ten entry/exit fixes (marked by the numbers around the edges).

In these experiments, two people jointly tackled the problem of successfully guiding 26 airplanes safely to their specified destinations without making a mistake. Subjects were in the same room watching the same display, but each had a separate keyboard for entering commands.

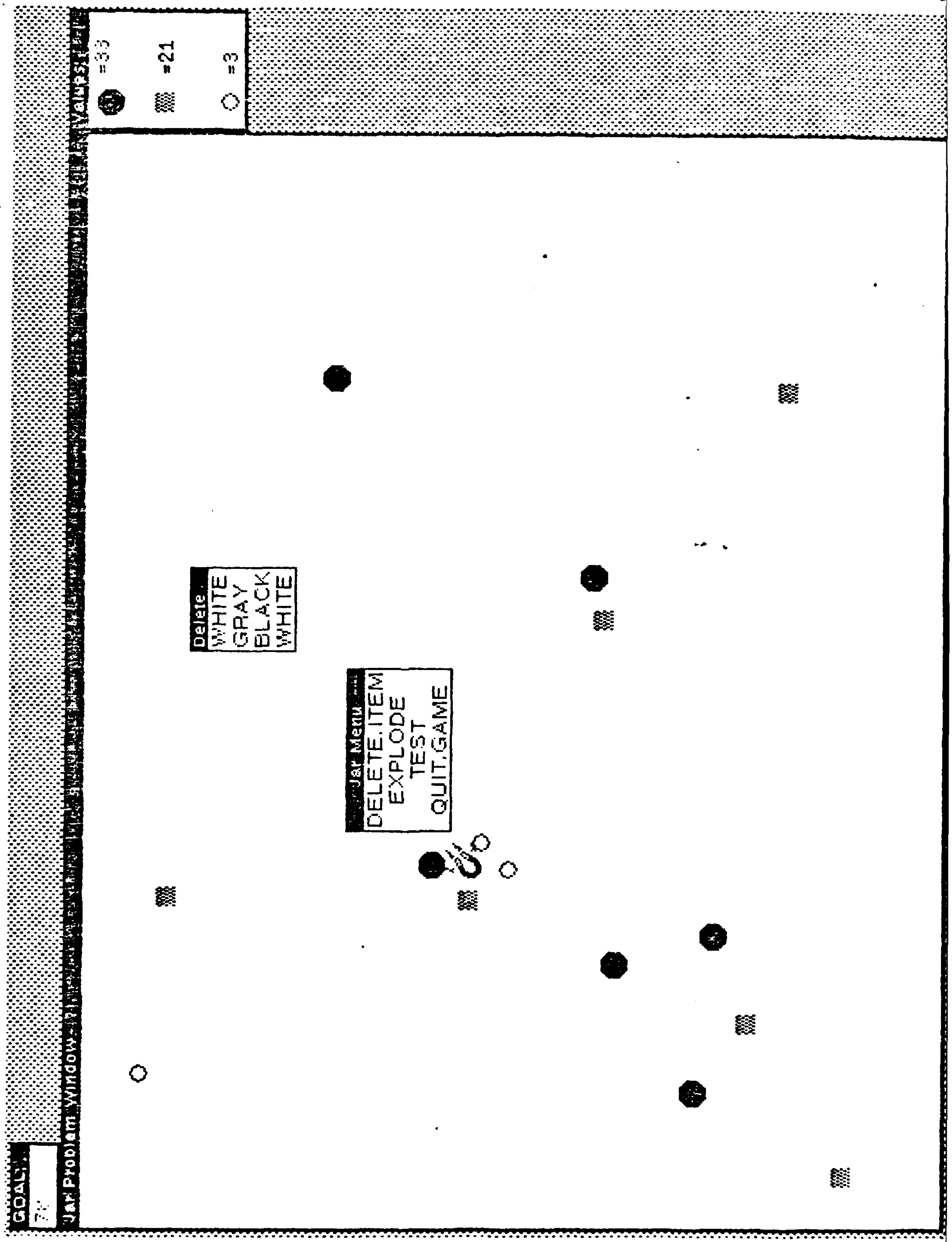

Figure 2: A Water Jar Problem Isomorph Microworld

Water Jar Isomorph Microworld

To further study the effects of shifts of point of view and to examine transfer of instruction, we have constructed an isomorph of the classic "water jar" problem (Luchins, 1942), in a way based on a modification of the Brownian Chemistry Microworld. In the Water Jar Isomorph Microworld, the problem solver rides a icon for a magnet, and moves it near the atoms and molecules moving dynamically in this world. Then, the solver builds up or takes apart these components, to build up a composite molecule with a specified target weight. We will examine point of view by looking at which components in this world are selected by the problem solver in which order. See a screen printout of this world in figure 2.

Water Jar Problem Experiments

In order to measure the transfer of point of view instruction on problem solving abilities, we conducted a set of experiments in which subjects solved the classic "water jar" problems (Luchins, 1942). In these problems, subjects are given a set of jars, and asked to measure out a certain amount of water. They can only fill up the jars completely, pour one into another, or pour out a jar. These experiments will form a base for transfer of training in the Water Jar Isomorph Microworld described above.

Crystalization Microworld

In order to explore the effects of point of view at the same level of organization, we have constructed a microworld game, in which attention by

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