DOCUMENT RESUME

ED 319 379 IR 014 397

AUTHOR Martin, Laura M. W.; And Others
TITLE Microworlds to Macroworlds: Conceptual Transfer and Activity Setting. Technical Report No. 46.
INSTITUTION Bank Street Coll. of Education, New York, NY. Center for Children and Technology.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE Dec 87
CONTRACT NSF-#TE1-8319705
NOTE 20p.; Paper presented at the Annual Meeting of the American Educational Research Association (Washington, DC, April 20-24, 1987).
AVAILABLE FROM Center for Children and Technology, Bank Street College of Education, 610 W. 112th Street, New York, NY 10025.
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Computer Games; Concept Formation; *Ecology; Elementary Education; Microcomputers; *Models; Pretests Posttests; Small Group Instruction; Student Attitudes; *Teaching Methods; Theory Practice Relationship; Transfer of Training; Worksheets
IDENTIFIERS *Microworlds; Paper and Pencil Tests

ABSTRACT

This study examined children's application of ecological concepts under conditions that were similar to or different from the conditions under which they first applied the concepts while playing a microcomputer-based ecosystems game. Two task dimensions were studied: (1) the form in which the information was presented (iconic or symbolic); and (2) the interactional setting in which children worked with the conceptual material (alone or in small groups). Subjects were 30 students from a mixed fifth-sixth grade class in a New York City public school; they were randomly assigned to two treatment groups. Baseline information about the children's attitudes and knowledge was collected. Following a 6-week experimental phase, children's applications of concepts from the microworld game were examined during individual paper-and-pencil tests involving two-dimensional images, small group discussions using real objects, and individual paper-and-pencil worksheets in an out-of-school setting. Results showed transfer of certain microworld concepts in some settings and application of some teacher-taught material. These conceptual gains were most clearly seen when children worked in small group settings. (16 references) (MES)

BANK STREET COLLEGE OF EDUCATION

CENTER FOR CHILDREN AND TECHNOLOGY

MICROWORLDS TO MACROWORLDS: CONCEPTUAL TRANSFER AND ACTIVITY SETTING

Laura M. W. Martin, Maxine Shirley, and Mary McGinnis

Technical Report No. 46

December 1987

610 West 112th Street / New York, New York 10025

MICROWORLDS TO MACROWORLDS:
CONCEPTUAL TRANSFER AND
ACTIVITY SETTING

Laura M. W. Martin, Maxine Shirley,
and Mary McGinnis

Technical Report No. 46

December 1987

MICROWORLDS TO MACROWORLDS: CONCEPTUAL TRANSFER AND ACTIVITY SETTING*

Laura M. W. Martin, Maxine Shirley, and Mary McGinnis

Computer-based microworlds present unique opportunities to study how a relatively brief exploration of an environment that embodies a distilled set of rules and representations can promote learning and instruction. The rules may be accessed in a tutorial fashion, in an exploratory fashion (McDonald, 1985), and qualitatively or quantitatively (White & Frederiksen, 1987). By clarifying relations between variables and making outcomes relatively consistent, microworld environments may lead children to detect patterns more easily (diSessa, 1987) and learn to control the essential features of a system. An assumption inherent in educational microworld design is that by engaging children in certain processes, their learning will transfer from the relatively circumscribed electronic environment to corresponding but more complex natural circumstances (Levin & Waugh, in press).

Helping people to utilize knowledge gained in one context under another set of similar circumstances is difficult to engineer (Lave, in press). Critical features of congruence between two sets of problems, for instance, often seem to exist solely in the eye of the beholder, especially when researchers work with novices who do not share the formal analysis of the situation with the experts (Lave, in press). The microworld can correct the variations inherent in a macroworld and thus better specify the region of shared or to-be-shared understanding between novice and expert (White & Frederiksen, 1987). For instance, the complex dynamics of an ecosystem can be simplified in an electronically driven model to highlight the interactions of selected elements.

In addition to their significance for learning, microworlds and electronic environments in general may play a role in the activities of the users and instructors vis-a-vis information presentation. These activities may depart from usual classroom patterns

*This paper is based on a poster session, *Microworlds as Motivating Environments for Instruction*, presented at the meeting of the American Educational Research Association, Washington, DC, April 1987. The work was conducted as part of the Bank Street College Mathematics, Science and Technology Teacher Education Project; Regan McCarthy, Project Director (NSF #TE1-8319705). Thanks to Loretta O'Dell who assisted with the data analysis, to Seth Chaiklin, Sol Magzamen, Jan Hawkins, and Karen Sheingold for their helpful comments and suggestions, and to the teachers and students of P.S. 183.

(Shay, 1980); for example, in order to access the computer microworld, children may be asked to work cooperatively in small groups The talk generated during such interchange may facilitate learning (Damon, 1984). Changing peer partners while mastering a microworld rule system may cause children to be explicit about their strategies and may, therefore, result in even greater learning and transfer. Thus, what may appear as extraneous in a formal analysis of the microworld elements may be central to the impact of an activity. Such informal factors may be seen as preemptive, hindering, or facilitative of learning (Laboratory of Comparative Human Cognition, 1986; Martin, 1985).

The effects of an instructional device on the transfer of learning and its effects on user activities may not be independent phenomena. The work of Wertsch, Minick, and Arns (1984) and others (Newman, Griffin, & Cole, in review; Martin, 1983) demonstrates that psychological functions (i.e., problem solving) develop from goals carried out as a function of interactions with others (Vygotsky, 1978). The effects of these mutual activity structures, however, have not been considered in the study of transfer of microworld concepts per se. Although attempts have been made to analyze novice-expert dynamics, it has been for the purposes of building their formal task-related components into a program (Shoenfeld, in press).

As part of a research project investigating teachers' uses of integrated technology to organize learning, a study was conducted to find out what upper elementary school students could derive from a brief experience with a microworld environment in order to speculate on the relationship of such environments to regular instruction. In particular, transfer of microworld concepts to other settings was examined, both in terms of formal problem requirements and in terms of interactivity. The study looked at several variables relating to the utilization of microworlds in an effort to tease out elements of pedagogical significance. Evidence was collected of children's utilization of ecological concepts in several functional settings before and after becoming familiar with an microcomputer-based ecosystems game. Textual and iconic written data as well children's verbal protocols and adult observations were examined.

METHOD

Design

This study was designed to examine the application of ecological concepts under conditions that were similar to or different from the conditions under which children first applied some of the concepts, that is, while playing a microworld game. Two task dimensions were studied specifically: the form in which the information was presented to children (e.g., iconic or symbolic) and the interactional setting during which children worked with the conceptual material (i.e., alone or in small groups). Baseline information about the children's attitudes and knowledge was collected. Following a 6-week experimental phase, children's applications of concepts from the microworld game were examined during individual paper-and-pencil tests in class involving 2-dimensional images, small-group discussions in class using real objects, and individual paper-and-pencil worksheets in an out-of-school setting.

Subjects

Subjects were 30 children from a mixed fifth-sixth grade class in a New York City public school, randomly selected and assigned to treatment groups. Fifteen children were assigned to the experimental group and 15 to the control group.

Materials

A pretest allowed us to check for initial biases among the children and between the groups in attitude towards science, tendency to select specific animals from an array, skill in reading and interpreting graphs, and skill in depicting interdependence of species. Pretest materials consisted of an individually administered paper-and-pencil test, which was comprised of:

1. A 10-question Science Attitude Questionnaire adapted from Mattheis, Spooner, & Coble (1985). Five positively phrased and five negatively phrased statements asked children to register their degree of agreement on a 1 to 5 scale. Scores were converted to a uniform scale, positive to negative.

2. Six multiple-choice questions asking children to choose a statement that best describes a graph. Two bar graphs and four line graphs of one and two functions were presented.

3. Two questions asking children to write a sentence to interpret single- and 2-function line graphs.

4. A picture of an environment for which children had to select inhabitants. Children were asked to pick 12 plant and animal species from an array of 30 labeled pictures, making sure "everything had enough to eat." Half the species choices were items appearing in the computer microworld. The array represented equal numbers of primary producers, primary consumers, and secondary consumers.

5. Three pictures of habitats (desert, forest, mountain) depicting plant and animal species, on which children were asked to draw an arrow between each animal and its source of food. If there was nothing for the animal to eat in the picture, children were asked to draw in a food source.

The software used by the experimental group was Island Survivors (Holt, Rinehart, & Winston, 1985), a component of *The Voyage of the Mimi* science and mathematics program. The aim of the Island Survivors game is to help three shipwrecked humans live on an island for a year without disturbing the ecological balance of the island's plant and animal species (which the players choose). The survivors must gather food, build shelter, and carry out other necessary activities. The game players see monthly status reports, in the form of graphs, of the food levels and the populations of interrelating species (see Figures 1 and 2). The software game module is meant to be used in conjunction with ongoing classroom study of the

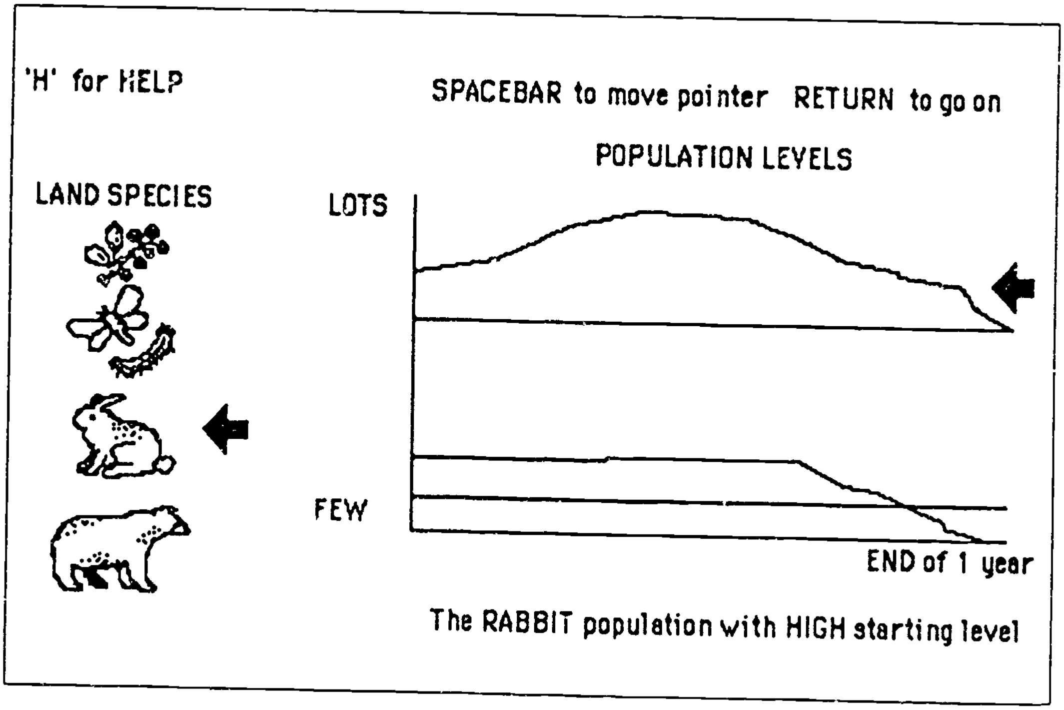

Figure 1. Screen from Island Survivors-1.

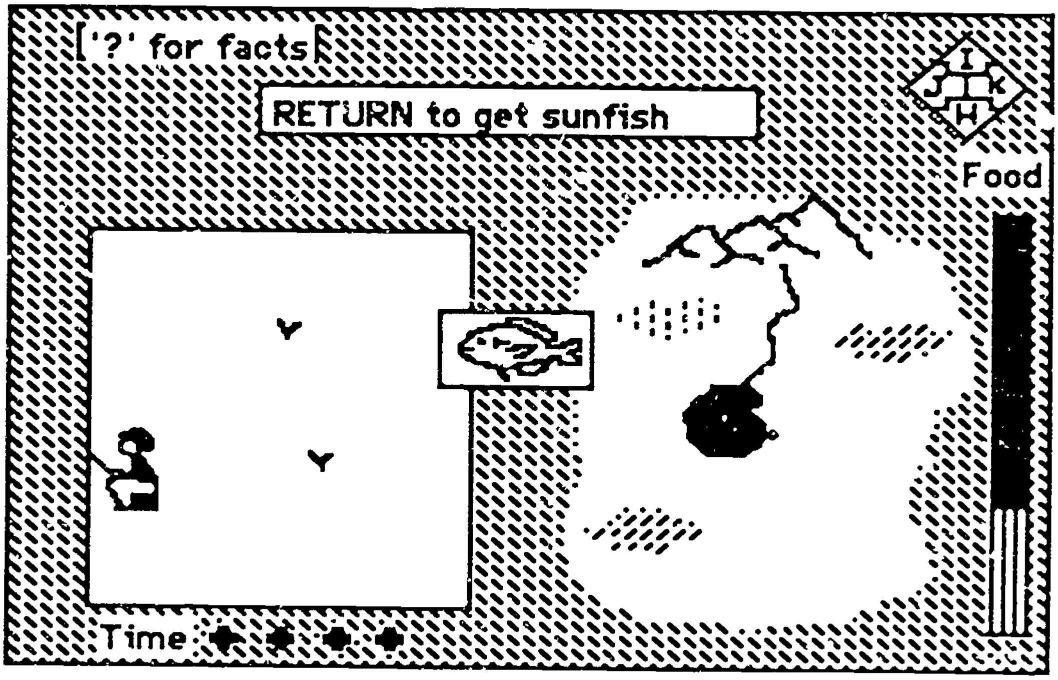

Figure 2. Screen from Island Survivors-2.

content area. Teachers are encouraged to introduce its concepts and features during class time.

The designers of this environment, when interviewed, specified several concepts built into the program that they hoped would be discerned by students and elaborated upon by teachers. These include, among others, the concepts of food chains, food webs, and population cycles, and the interdependence of species. The game variables function according to a valid but simplified mathematical model, which the teacher may choose to discuss with students.

The software used by the control group included: Operation Frog (Interactive Picture Systems, Inc. and Scholastic, Inc., 1984), The Pond (Sunburst Communications, Inc., 1984), Discover (Sunburst Communications, Inc., 1985), and The Incredible Laboratory (Sunburst Communications, Inc., 1984, 1985, 1986). These software modules vary in difficulty and do not cover the concepts treated in the Island Survivors game.

The post-test materials were as follows: Post-test I was a readministration of the pretest. Post-test II was a vivarium construction task (described below) in which children working in small groups were asked to select items from an actual array to inhabit a vivarium. The array also included a 5-gallon glass tank and a clip-on tank light apparatus. Post-test III consisted of a group walk in a park. Children were given individual question forms, pads of paper, and pencils. The question forms asked them to: (a) observe and identify organisms living in the park; (b) identify threats to park survival; (c) determine population sizes for these species; (d) diagram the food chains in the park; (e) identify the park pond's species; (f) identify park support systems and the role of humans; and (g) identify possible park species from a list of 10 items, half of which were species from the Island Survivors modules. Questions were chosen so as to make it possible to trace concepts acquired from the microworld, from the teacher's lessons, and from general experience.

Procedure

The classroom teacher administered the pretest to the children during a regular class period. Three weeks after administration of the pretest, all the children were given a brief introduction to the software by the experimenter. Computer work was carried out during a regularly scheduled 40-minute computer lab period over a 6-week period. The computer teacher and her assistant, the homeroom teacher, and the researcher and her assistant were present to answer children's questions and note the problems that occurred, as well as to observe the children's game-playing.

The experimental group worked on the Island Survivors computer module until the criterion of one year's survival for all species was achieved (approximately six class periods). Children worked in groups of three; three groups rotated membership and two remained constant. The rotation condition was included to see whether changing partners demanded that children elaborate their strategies and whether this resulted in better transfer. The control group worked on other science software over the same period of time, rotating modules. Again, children worked in groups of three.

All children received regular classroom instruction from the homeroom teacher on principles of ecosystems, in particular, the energy cycle, which was a unit for the class. During the time the experiment was being carried out, the teacher relied on a textbook and on her own experience for lesson ideas; she conducted classroom discussions and had the children draw representations of the energy cycle. Instruction earlier in the year had included field trips and hands-on experiences.

One week after the software phase ended, the pretest was readministered. One week after that, the researchers met in the science room with each group of three to conduct the second post-test, which was administered to the groups of three who worked together on the computers. Children were asked to select items from an actual array for assembling a self-sustaining vivarium and to discuss their selections. They were not asked to actually assemble the environment. The items presented included some real objects (e.g., rocks, soil, various plants, water) and some symbolic (e.g., rubber snake, mouse, frog, insects), some "intruder" items (e.g., plastic bird, rubbish) and some nonreproducible food sources (e.g., bread, lettuce, food pellets). The children were told the fake animals stood for real ones. The sessions were recorded on audiotape and later transcribed for analysis.

Approximately two weeks later, the children were taken for a walk to a nearby park by their homeroom teacher and the researcher and her assistant (Post-test III). They were told to walk around the park for approximately 20 minutes, conduct their observations, and write down their answers on pads and question sheets, which were collected for analysis.

RESULTS

Results of the study showed transfer of certain microworld concepts in some settings as well as application of some teacher-taught material among children who had experience with the model ecological system. Results also showed that these conceptual gains were most clearly seen when children worked in small-group settings, as they had when they interacted around the microworld.

Individual In-Classroom Paper-and-Pencil Tasks

The paper-and-pencil tasks given to the children as individual pre- and post-tests in their classroom were designed to share features with the screen representations children saw in the computer microworld. An attitude scale was included as a traditional measure of change in general individual motivation as a function of a particular experience or treatment.

T-tests of the pretest measures showed no initial differences between groups. In addition to similar and mildly positive attitude scores, the children chose equivalent amounts of producers and consumers or game and nongame animal representations to inhabit the scene and they performed similarly on the graphing questions. Finally, they indicated equal numbers of food chains and webs in the three pictured habitats. The results of the first post-test are discussed below:

1. A mean attitude score for each child was calculated by averaging the 10 attitude scale responses. On the first post-test, t-tests comparing pre- and post-test scores showed a positive tendency in the attitude scores of the experimental subjects (M= 4.07, t[14]= -1.99, p< .06), while controls showed no shift from their pretest attitudes. The individual attitude scale did not appear to capture effects of the intense involvement the children exhibited while playing the microworld game (in contrast to the children using the other software), noted in the researchers' observations.

2. While playing the game, children had exposure to three sets of dynamic graphs —two multi-function graphs and one bar graph—whose interpretation could help the players improve their game. The children were presented with this visual information but were not asked to respond directly to it by inputting interpretations, nor were they required to interpret the graphs in order to play the game. During playing time, groups of children varied in the extent to which they consulted and studied the graphs. Observers noted that, in general, children's tendencies to consult the graphs increased during the time they were exposed to the game.

Subsequently, when asked to recognize correct written interpretations of line and bar graphs among four choices, experimental subjects' performance improved significantly (M=4.73, t[14]= -2.58, p<.02), while control subjects showed no change in performance (M=4.13, t [14]= -0.40, p<.70) between the pretest and post-test. However, all children tended to have more difficulty reading the 2-function graphs than the single function line and bar graphs; these differences were not analyzed in the present study.

3. Children's own written interpretations of two line graphs were ranked on a scale of 0 to 4 according to whether the child (a) read the graph incorrectly; (b) interpreted one point on the graph; (c) interpreted one or two variables on single- or double-function graphs, respectively; (d) interpreted three variables; or (e) expressed a correct inference or generality about what the graph was displaying. Children's mean score on the pretest was 1.52. No changes were seen in the written interpretations of graphs for any groups on the post-test.

4. Pilot interviews with children suggested that they tended to notice and prefer animals at the top of the food chain. For this reason, a species selection task was included to see whether a microworld experience could help children notice animals and plants at other levels of the food chain. Here, children selected equal numbers of species at each level on their pretests. Thus, there could be no effect of the game on helping children to think in terms of different levels of food chains, since they already did. Furthermore, there were no significant differences between the subjects in experimental and control groups or between the rotating and nonrotating groups

on the number of producers, primary consumers, and secondary consumers chosen on post-tests, and these did not change from their pretest choices.

While no initial bias was seen for or against the animals included in the software program, on the first post-test experimental subjects chose significantly more species in the microworld (M=8.47) to inhabit the pictured environment than they had in the pretest (M=6.67, t [14]= -4.10, p<.001). Changes among control subjects' choices were not significant. Thus, for individual children the game increased the salience of particular species when they appeared in an iconic array. The number of Island Survivors species chosen among children who rotated groups and those who didn't increased equally.

5. Another individual paper-and-pencil measure asked children to iconically represent concepts they may have learned. The numbers of food chains and webs identified and labeled by experimental and control children were scored according to the number of multiple-link representations present. The group means did not differ (M=1.87 and 2.07) and did not change from the pretest to the post-test. On these tasks, children overwhelmingly indicated single animal/food source relations. Double chains and webs were rarely drawn. There were no differences in the number of nonreproducible food sources drawn by the children in the two groups (M=1.53 and 2.13).

In sum, the written measures of the first post-test revealed some carryover of operation (reading line and bar graphs) and image recognition (animal icon choices) from the microworld. Children's enthusiasm for the software was not strongly captured by a general attitude scale. On other measures that demanded novel actions with respect to concepts, such as linking food chains and writing interpretations of graphs, children did not show gains in individual application after having had a chance to use the ecosystem software.

Small-Group In-Classroom Discussion

On the second post-test, children were asked to discuss and select items from an array so that a self-sustaining environment could be created in a glass tank. The items represented all levels of a food chain and, with one exception (a turtle), were not species that were part of the Island Survivors game. Water, a light source, and substrate material were also in the array. The problem was chosen as one in which children could apply their awareness of the interrelationship of ecosystem elements while working in the same small problem-solving groups they had been while using the computers. Evidence for the application of energy cycle concepts covered by the teacher during her unit was also studied.

Children's utterances during this task were scored, by group, for the presence of particular concepts. Two raters analyzed the transcribed protocols (interrater reliability=.91). In addition, the lists of items children generated to place in the vivarium were scored for the presence of supported items, intruder items, and nonreproducing food items. Chi-square one-sample analysis of the number of relevant statements made during the sessions showed that the children in the experimental groups expressed a greater awareness of concepts stressed in the Island Survivors game, namely, the need to provide a source of food for organisms (M=9) than did the control group children (M=4, $\chi^2[1, N=10]=9.62, p<.01$). They also more often expressed the ideas of food chains (M=9.4; M=4.0, $\chi^2[1, N=10]= 11.86$, $p< .01$); of interdependence of organisms (group M=9; M=4.6, $\chi^2[1, N=10] =6.48, p< .05$); and of population cycles (M=1; M=0, $\chi^2[1, N=10]=5.00, p<.05$). In addition, control groups tended to generate more associative (M=5.2 vs. M=3.8) as opposed to interdependent descriptions of pairs of items. "A snake goes on a rock" is an example of an associative statement; "The snake can eat the mouse" is an example of an interdependent statement. Differences were not related to the number of comments made or list lengths in groups, although the utterances of the experimental subjects were noticeably more complex and lengthier. No differences were seen between rotating and nonrotating groups.

For the teacher-taught concepts, experimental groups noted water as a survival necessity (M=2) significantly more often than did control groups (M=.2, $\chi^2[1, N= 10]=6.54, p<.05$). While not significant, among the experimental groups there were trends towards a greater awareness of issues of shelter and the need for substrate, and for control children to choose more unsupportable species and nonreproducing food sources. No differences were seen between the groups in the awareness of the need for a light source. Table 1 shows these results.

Thus, when children worked in the small-group classroom situations as they had while interacting with the microworld, whether or not with constant partners, they were able to apply many of the microworld concepts to a new set of materials representing an ecosystem. Furthermore, the application of related concepts presented by the teacher during class time was somewhat facilitated during the small-group discussion.

Individual Out-of-Class Paper-and-Pencil Tasks

In order to see what concepts from the ecosystem microworld may have transferred to a nonschool setting, the children were taken out to a neighboring park and asked questions that tapped microworld concepts, teacher-taught concepts, and general knowledge about the environment. The children were asked to create written lists, to generate schematic representations and, on one question, were presented with verbal references to microworld species.

Although the children were instructed to work alone, observations of the researchers and similarities among some answer sheets revealed that most children consulted with their friends during the walk. Because limited staffing precluded separate walks with the experimental and control groups, the children's answers cannot then be considered a clearly valid measure of individual thinking in a nonschool setting.

Table 1

Differences in Numbers of Types of Utterances on the Vivarium Task Among Treatment Groups

	Group		
Utterance Type	Experimental	Control	χ^2
References to food	45	20	9.62**
References to water	10	2	6.54**
References to light	3	2	n.s.
References to shelter, substrate	13	8	n.s.
References to food chains	47	16	11.86**
References to interdependence of species	45	23	6.48
Association statements	19	26	n.s.
Intruding species	9	17	n.s.
Nonreproducing food sources	4	6	n.s.
Population cycles	5	0	5.0*

Note: The values represent group total.
$n = 15$; $n = 15$.
$*p < .05$; $**p < .01$.

Children's written responses on the park walk question sheet (Post-test III) were scored by two raters who together assessed responses qualitatively and quantitatively. No differences between children were seen in their displays of microworld concepts, teacher-instructed concepts, or general knowledge, although there were trends towards greater application of microworld and teacher-taught concepts among children in the experimental groups. Results on one measure from the park walk—awareness of human impact—were discounted because more than half the children didn't answer the question on their response sheets.

Thus, similarities between experimental and control groups were seen in the number of species named and inferences made about species living in the park from indirect evidence (general knowledge), including the number of unreasonable items inferred (e.g., cactus), dangers to the park environment (general knowledge), population levels estimated for park species (microworld concept), the number of food chains identified in the park (microworld concept), light and water as necessities (teacher-taught concept), and pond supports (teacher-taught concept).

In the generation of lists, in their representations of abstract relations, and in their selection of written choices, experimental and control children, who often worked together, performed equivalently. Furthermore, the absolute numbers of credited responses were low as opposed to uniformly high, suggesting that information individuals came in contact with in the microworld was not applied or shared among children in the nonschool, paper-and-pencil situation. Children's diagrams of the park food chains, with three exceptions in each group, did not present information in a schematic way, indicating that the microworld's abstract form of presenting information was not readily applied in this context. Finally, experimental and control children identified equal numbers of species from the computer module as probable park species on a multiple-choice question.

DISCUSSION

In the Island Survivors microworld, players help shipwrecked humans survive for a year on an island without disturbing the balance of nature. The Island Survivors game was designed to convey concepts of ecological systems, and includes graphed representations of relations between factors in the ecosystem over time. It was intended to be used by small groups of children in conjunction with ongoing noncomputer-based classroom activities.

The game was a popular and favored activity for the children who played it. In contrast, the more delimited environments of the other science software produced some signs of boredom among the control group children, such as requests to change software. The appeal of the experimental software, although not reflected in a written science attitude scale (see Shaw & Okey, 1985) was evidenced by the children's questions, their eagerness to resume playing at each session, and their intense discussions during computer time. It can be said that the children were eagerly bringing themselves in contact with the information contained in the program.

Th study sought to discover what children learn when working with the information-rich system of a microworld on a relatively short-term basis. What elements in the learning process in this situation can be used as bridges to learning in other situations?

To address this question, paper-and-pencil tasks were designed to share features of the screen representations that the children saw in the computer microworld and to get them to respond to the representations in ways that were both similar to and different from the game's demands. Problem-solving tasks that mirrored or varied the interactional conditions of the microworld experience were also included. Thus, a written test asked children to work alone with limited graphic elements; a vivarium task presented children with a group activity similar to the species selection, survival, and strategizing tasks of the microworld, using real objects; and a park walk was designed to see what children might apply from a microworld to a social and experiential "macro" world, as evidenced by their written reports.

Analysis of children's written and oral protocols showed certain advantages to mastering the Island Survivors microworld rules for learning and applying concepts of ecology and graphing. These were seen in two activities: a paper-and-pencil task presenting graphic information and task demands in a format similar to the software's, and a decision-making task involving 3-dimensional objects presented in interactional circumstances similar to the microworld task (i.e., small groups). That is, transfer of concepts to new material appeared to occur when children were asked to respond to images that were directly comparable to the game's, or in different modalities through the vehicle of comparable interpersonal activity.

Deriving information from the condensed material of the microworld, then, seemed to be mediated by the form of the information presented and by the interactive setting in which activity with the microworld occurred. For example, subjects in this study were asked to select icons of primary producers, primary consumers, and secondary consumers to inhabit a pictured scene. Following the computer experience, experimental subjects tended to choose species from the game to inhabit pictured scenes when they saw similar icons. Overall, they did not show this bias during discussion or on a written species name selection task in a familiar park environment.

The park, however, is a well-known nonschool environment. In this familiar, out-of-school situation, nonschool forms of interaction predominated. Children conducted themselves in what can be called a "jail-break" manner—running, shouting, and scattering quickly in friendship groups. Information was seen to be shared among the children such that little advantage to school-learned information obtained, although this study did not allow us to show whether what was learned in the microworld by some of the children helped all of the children to answer questions. While their responses to park questions showed fairly reasonable guessing and everyday understanding about the park as an environment, there was some puzzlement as to what was being demanded of them in the question sheet, as evidenced by many omissions in responses. There may be another set of understandings relating to nature, not easily perturbed by the microworld, that dominates in the park, especially when questions can be answered from everyday experience.

That both the form of the information and its interpretive setting influence its reappearance in other circumstances was demonstrated in the results of the graph interpretation task. Individual ability to recognize a correct interpretation of bar and line graphs was directly facilitated in a visually equivalent setting. In contrast, when they were asked individually to write textual interpretations of graphed information, all students' answers tended to focus on one variable rather than on two or three, or to express a literal reading of the graphs rather than an interpretation despite the fact that during the game the children discussed the graphs and their meanings. In the vivarium construction task, which did not share iconic features with the game, children in the experimental group were heard to generate discussion of complex interrelations of the kind that had been graphed (see below).

Conceptual material presented in the microworld was also subject to interaction structure effects. Experience with Island Survivors led children to consider the need to support species all along the food chain during subsequent discussion, but not necessarily to be able to depict these food chains on pencil-and-paper tasks. A suggestion of discriminate evidence for their conceptual gain was seen in the fact that children from the control groups tended to choose more nonreproducing foods and unsupported species. The microworld's schematic representation of the food webs did not carry over to a writing task, but the need to consider the interdependent relations of species in discussion did. Similarly, children considered population cycles of growth in their discussions.

During the vivarium task, discussions among the children demonstrated the relative conceptual richness in the experimental group about relationships among the items. Differences in the quality of children's talk were marked. Consider the comments from each group concerning the inclusion of plants in the vivarium, where the comments of the children in the experimental group on the whole reveal more complex relationships and associations.

Experimental Children

Group 1: "Some fish and turtles can eat off this."

Group 2: "Put in a green plant"; "Plant plants so you wouldn't need to add anything"; "Lettuce seeds could grow."

Group 3: "Plants, so other animals can eat it"; "Soil is needed for the plants."

Group 4: "Plants go in soil"; "Plants grow into a tree and the bird lives in it and makes a nest."

Group 5: "Plants, so animals have it to eat"; "Snake eats the mouse and the mouse eats green plants"; "Plants are pondweed. Fish—bass and sunfish—eat pondweed."

Control Children

Group 1: "Plants, to keep the fish alive"; "Plants are at the bottom of the ocean, water plants."

Group 2: "The turtle eats plants."

Group 3: "Seaweed and plants float on water."

Group 4: "Tree, the bird lives in it"; "Cactus would make a desert"; "Some plants are under water"; "Snakes crawl around trees."

Group 5: "Plant" [included with no comment].

It was as if the problem-solving discussions transferred to this new setting, and were characterized by talk full of curiosity, speculation, and amusement.

Since we did not test children individually on the vivarium task, we do not know how elaborated any verbal responses to an interviewer or written questions might have been. However, many of the elaborations we heard in which ecological concepts were embedded were clearly co-constructive in nature; that is, the concepts emerged as the children responded to the content of each other's utterances:

Child 1: The snakes eat the toads; they squish them.
Child 2: Yah, put the snake, the toad, the fish..
Child 3: Let's pretend this is a rock...
Child 2: Oh! And a fly!
Child 1: Yah, the frog, the turtle, and the fly...
Child 2: And the frog eats the fly!
Child 1: And the fly eats the beetle!
Child 3: It can't live in water!
Child 1: We're not putting water in there. Are we?
Child 2: (laugh) If you don't have no water you can't have fish

We conclude from this kind of evidence that the interactive setting is the mechanism through which the experimental concepts come to be applied.

Rotating group membership, and hence needing to elaborate on game strategy to new people, did not mean that children learned more or were more influenced by the game elements than were the children who worked consistently with the same partners. This result may be due to the fact that the children generally cooperated so easily that little explanation of strategies was necessary.

Water, light, and substrate were concepts not directly covered in the computer microworld, but rather in the teacher's class lessons. Experimental groups did tend to consider water and, to a lesser degree, substrate to be necessary elements of the ecosystem in their discussions about the vivarium. The need for light, however, another concept introduced by the teacher, was not mentioned often by children in relation to the vivarium. Their remarks suggested that the presence of a light bulb apparatus was puzzling to many of them. Although the results of the park walk were difficult to interpret, nonsignificant trends suggested that, following the microworld experience, children noticed light, water, and pond concepts from the teacher's lessons in that context to a greater extent than did their control group counterparts.

Over the course of the study, the classroom teacher carried on routine instruction. Earlier in the year she had emphasized pond ecology, which was noticeable in children's choices of animals on the pretest. The teacher felt that the microworld experience was important for her own instruction because children's talk about the game provided conceptual bridges to the material she had introduced.

Since the teacher did not deliberately build on the game concepts nor on interpretation of graphs and diagrams, the microworld representation remained a parallel universe to the classroom. However, group work was in common and mediated transfer of the microworld concepts to other settings. It was noted, too, that after the study was concluded, the children who had mastered the microworld system eagerly worked with their novice peers, who learned the game in a relatively shorter time.

The nature of the effects and trends in the current work suggests that in the future, rather than concentrating solely on individual fact learning and application, it might be fruitful to study microworlds for their relations to instructional interactions. School is essentially a social place where a lot of group activity occurs. If the condensed rules of the microworld manifest themselves either in the presence of equivalent representations (e.g., images) or during equivalent activity in relation to the conceptual material (e.g., joint problem solving), then they are of significant value for promoting transfer when they are used by learning groups. When children engage in regular discussions and collective explorations, conceptual material can be expanded through these interactive routes because the elaboration does not depend upon a correspondence of features between different worlds.

REFERENCES

Damon, W. (1984). Peer education: The untapped potential. *Journal of Applied Developmental Psychology, 55*, 67-75.

diSessa, A. A. (1987). Artificial worlds and real experience. In R.W. Lawler & M. Yazdani (Eds.), *Artificial intelligence and education* (Vol .1). Norwood, NJ: Ablex.

Laboratory of Comparative Human Cognition. (1986). *Non-cognitive factors in education.* Report to the National Research Council.

Lave, J. (in press). *Cognition in practice.* New York: Cambridge University Press.

Levin, J. A., & Waugh, M. (in press). Instructional simulations, tools, games, and microworlds: Computer-based environments for learning. *International Journal of Educational Research.*

Martin, L. M. W. (1983). *Children's problem solving as inter-individual interaction.* Unpublished dissertation, University of California, San Diego.

Martin, L. M. W. (1985). The role of social interaction in children's problem solving. *Newsletter of the Laboratory of Comparative Human Cognition, 7*(2), 40-45.

Mattheis, F. E., Spooner, W. E., & Coble, C. R. (1985, August). *A study of the logical thinking skills, integrated process skills, and attitudes of junior high school students in North Carolina.* Raleigh, NC: East Carolina University, Greenville, and the State Department of Public Instruction.

McDonald, J. P. (1985, January). *Microworlds and expert systems: Is it either or can it be both?* Cambridge, MA: Educational Technology Center.

Newman, D., Griffin, P., & Cole, M. (in review). *The construction zone: Working for cognitive change in school.*

Shaw, E. L. Jr., & Okey, J. R. (1985, April). *Effects of microcomputer simulations on achievement and attitudes of middle school students.* Paper presented at the meeting of the National Association for Research in Science Teaching, French Lick Springs, IN.

Shay, C. (1980). Simulations in the classroom: An appraisal. *Educational Technology, 20*(11), 26-31.

Shoenfeld, A. H. (in press). Mathematics, technology, and higher-order thinking. In R. S. Nickerson (Ed.), *Technology in education in 2020: Thinking about the not-distant future.*

Vygotsky, L. S. (1978). *Mind in society.* Cambridge: Harvard University Press.

Wertsch, J., Minick, N., & Arns, F. J. (1984). The creation of context in joint problem-solving. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context.* Cambridge: Harvard University Press.

White, B. Y., & Frederiksen, F. R. (1987). Qualitative models and intelligent learning environments. In R. W. Lawler & M. Yazdani (Eds.), *Artificial intelligence and education* (Vol. 1). Norwood, NJ: Ablex.