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ABSTRACT

A research program was undertaken to study the functional learning environment (FLE) in which computers operate, i.e., those environments in which learning activities have a function or purpose from the child's viewpoint. Results of three projects illustrate the importance of teachers in creating and interpreting children's learning environments. The first project was designed to determine whether experience with LOGO programing would enhance third and sixth grade children's planning skills; no effects on planning were found. The second project involved one aspect of the Bank Street College Project in Mathematics and Science Education, in which a FLE is based on a multimedia simulation of a science show. Results indicated that the materials were successful from the children's viewpoint, while teachers' evaluations were mixed. The third project investigated whether networking can be used as a FLE for writing and communication. The three studies raise fundamental questions about the design and implementation of FLE's, particularly the relationship between the children's purposes and those of their teachers. It is concluded that coordination of divergent purposes within a FLE is a critical factor in the success of classroom microcomputer activities. Twenty-one references are listed. (LMM)

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FUNCTIONAL ENVIRONMENTS FOR MICROCOMPUTERS IN EDUCATION*

Denis Newman

Introduction

For the last several years, researchers at the Center for Children and Technology have been conducting a program of research on the use of computers in education. One of the central themes of this research is that the computer is a tool that can be used for a variety of functions or purposes. Thus, we talk about the computer operating within a "functional learning environment" (FLE). Here, functional means that the learning activities have a function or purpose from the point of view of the child. In this paper, I discuss three projects undertaken at Bank Street College in which we implemented and studied such environments. These studies raise fundamental questions about the design and implementation of FLEs, particularly the relationship between the children's purposes and those of their teachers. Coordination of divergent purposes within a FLE turns out to be a critical factor in the success of classroom microcomputer activities.

While research on microcomputers is relatively new at Bank Street, concern for FLEs is quite old. Since its beginning in 1916, the college has been at the forefront of the progressive education movement founded by John Dewey. A central theme in Dewey's (1902, 1938) writing on education is the notion that classroom activities must be related to the child's experiences, interests, and goals. This was a radical proposal for an era in which the teacher stood at the front of the class and lectured or conducted drills. Although the general notion has found wide acceptance in United States schools in recent decades, many teachers find it impossible to implement because of limited resources, materials, and training. It is the hope of many people in the field of educational computing, including staff at Bank Street, that the microcomputer can be a resource for engaging children's interest and fostering a more creative learning process.

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In this paper I will first describe the notion of FLE in more detail, and will then present observations about three projects that have tried to create FLEs. These projects concern the use of the Logo language in Bank Street classrooms, a project on science and mathematics education, and the creation of a network of microcomputers. In each case, the observations illustrate the importance of coordinating the goals of children and teachers.

Functional Learning Environments

We start with two assumptions: (1) Children are intrinsically motivated to work on tasks that are meaningful to them; and (2) The most effective educational environment is one that provides meaningful tasks, i.e., tasks that embody some function or purpose that children understand. While some children enjoy learning about a particular topic "for its own sake," in most cases, facts and skills are best learned in connection with larger tasks that give them significance or meaning. In this way, not only are children motivated to master the facts and skills, but they have a framework in which to understand the cultural significance of the facts and their relation to other facts. For example, a science project in which children attempt to answer specific questions about whales and their habitats by constructing a database provides an environment for learning scientific categorization schemes as well as specific facts about whales. It can also demonstrate to the children the variety of resources--such as textbooks, encyclopedias, and films--that are available in our culture for obtaining the facts, and confront them with the need to cull information from several sources.

Our assumptions, however, leave two fundamental questions unanswered. First, we must understand where the goals that the children are interested in come from--are they inventions of the children or are they imposed by the teacher? Second, we must understand the relation between the goals that children undertake in the classroom and the tasks they will be confronted with in the real world outside of school. Unless students can apply the knowledge and skills they have acquired in school to tasks outside the classroom, any FLE will have been for naught.

Our approach to the first issue takes a middle position between the idea that the teacher must impose problems and the idea that children must invent their own classroom activities. On the one hand is the traditional view of education, and on the other is a radical version of the child-centered approach to education based on interpretations of the writings of Dewey as well as Piaget (1973).

It is very clear that Dewey felt that the purely child-centered approach was as erroneous as the traditional view that the teacher must impose the classroom tasks. The teacher has very important responsibilities which include suggesting tasks and presenting to the children alternative interpretations of problems. In many respects, Dewey's approach is more consistent with the socio-historical approach to child development presented in the recently published writings of Vygotsky (1978) and Leont'ev (1981), in which the importance of the teacher-child interaction is emphasized, than with the universalist approach of Piaget, which deemphasizes the cultural context (Laboratory of Comparative Human Cognition, 1984). According to these theorists, the child's initial attempts to solve an arithmetical problem, write a story, or operate a computer program are carried out in interaction with teachers or more experienced children. What the child internalizes is not what the expert says, but a version of the interactions that constituted the joint activity. Thus, without coercion, these interactions guide children toward the cultural interpretation and significance of the tasks in which they are engaged (Newman, Riel & Martin, 1983).

Meaningful tasks may come from a variety of sources. One source is the spontaneous ideas of the children themselves: most children have some topic which they simply "like." However, for most school topics this source may not be the most important. Teachers can make classroom tasks meaningful by showing children their significance in terms of a variety of uses for the skills involved, or in terms of the adult world they will be entering. The FLE created in this way can be a simulation of a real problem (e.g., role-playing commercial transactions as a context for doing arithmetic calculations), or it can be a real problem (e.g., actually selling food at a school fair to raise money to buy a classroom computer). The FLE can also be of a more abstract nature (e.g., a geometric problem can provide a meaningful context for calculating the size of an angle, providing that geometry itself has meaning within the children's experiences). A teacher can create interesting FLEs by crossing traditional discipline boundaries (e.g., by showing how geometric concepts such as triangulation can be used in geography to solve navigation problems).

Our approach to the second issue--the relationship between classroom and real world goals--is closely related to the first. We suspect that the usability of school learning in later life is inseparable from the variety of FLEs in which it is embedded. Being able to see the same fact from multiple perspectives (i.e., recognizing the different uses it can have) engenders a flexible approach to acquiring knowledge that would otherwise be absent. This flexibility makes it possible to adapt the knowledge to new functional environments that cannot be specifically anticipated in the classroom.

Microcomputers can play a very useful role in FLEs because of their capacity for simulation and because they themselves are important tools for the solution of a variety of interesting real world problems. They also provide fluid and manipulable symbol systems in which many interesting abstract problems can be represented and solved. But they cannot be expected to function on their own. A teacher must build the bridges between the tool, the school task, the thinking skills, and their functional significance for the culture beyond the classroom.

Logo in a Classroom

Logo is a programming language popularized by Seymour Papert (1980) and colleagues. According to Papert, Logo is an environment in which children can learn fundamental mathematical concepts and powerful problem-solving methods without the intervention of teachers. Papert takes his inspiration from Piaget, who has argued forcefully that

> each time one prematurely teaches a child something he could have discovered for himself, that child is kept from inventing it and consequently from understanding it completely. (1970, p. 175)

One of Piaget's (1965) earliest examples was the game of marbles played by boys from preschool to adolescence. In Switzerland, where Piaget studied the game, adults were not involved. The children learned from each other. Not only did the children master the complex rules of the game, but they came to understand that the rules were not absolute but a matter of convention and agreement among equals. The same kind of process is at the heart of Papert's claims for Logo: Without the imposition of adult authority and adult ideas, children can come to an understanding of the nature of concepts such as recursion that are as fundamental to programming as cooperative agreement is to games with rules. Of course, the peer play group for marbles included undisputed experts; the same may not be true for programming, which is seldom mastered by young children. This weakness in the analogy might lead us to question peer interaction as a basis for learning programming.

The initial interest in Logo at Bank Street, however, was not in testing its adequacy as a peer group FLE but with quite a different question. Researchers from the Center for Children and Technology set out to see if experience with programming would enhance planning skills in children. It was a reasonable hypothesis since writing a program is like creating a plan for the computer to execute. The question was whether there was any transfer from the activity of programming to other experimental tasks that also required making a plan of action but did not involve computers.

The researchers arranged to do their study in two classrooms at Bank Street's School for Children (SFC). The teachers in the SFC are highly committed to the child-centered approach to education, and were eager to try out Logo and the pedagogy developed by Papert. Neither teacher was an expert programmer, although each had taken a course with Papert prior to the study. The teachers were, however, experts in creating functional learning environments for children and approached the new task with enthusiasm.

For two years, the researchers observed and interviewed the children and teachers in the third and sixth grade classes. Pre- and post-tests were administered using a chore-scheduling task based on the work of Hayes-Roth and Hayes-Roth (1979). The findings concerning the transfer of Logo experience to the experimental planning task were very clear: the researchers found no effects at all (Pea & Kurland, 1984). By the time the researchers compiled their data, however, the negative findings came as little surprise. Observations of the children as they interacted with Logo and with each other showed that very little planning was involved in their programming practices. Thus, there was little reason to expect programming to make children more planful.

As Pea (1983) observed:

> Much more common was on-line programming, in which children defined their goals, and found means to achieve them as they observed the products of their programs unfolding on the screen. Rather than constructing a plan, then implementing it as a program to achieve a well-defined goal, and afterwards running the implemented plan on the computer, children would evolve a goal while writing lines of Logo programming language, run their program, see if they liked the outcome, explore a new goal, and so on.... In most cases, children preferred to rewrite a program from scratch rather than to suffer through the attention to detail required in figuring out where a program was going awry. As one child put it when asked why she was typing in commands directly rather than writing a program: "It's easier to do it the hard way."

From the children's point of view, Logo was for the most part an interesting classroom activity, although there were certainly differences among the children in their level of interest and in the amount of programming that they learned. But, despite their enthusiasm, they did not explore the more conceptually challenging aspects of Logo in the course of their discovery learning. They were essentially "playing." In Piaget's (1962) terminology, assimilation was dominating accommodation; that is, the goal was assimilated to the procedures rather than the procedures being accommodated to a set goal. Whatever worked became the goal retrospectively.

From the teacher's point of view, the children were engaged in the Logo activity but were not learning to program. Experiments involving the better Logo programmers showed that few had correct understanding of such central concepts as flow of control, conditionals, or recursion (Kurland & Pea, 1983). As time went on, the teachers began to question the discovery-oriented approach to teaching programming. It became clear to them that Logo could not just "happen," but that they, the teachers, had to have an idea of what they wanted the children to get out of the activity: goals had to be set, activities had to be formulated, and the teachers had to come up with effective ways of getting their ideas across to the children. The teachers themselves wrote a book (Burns & Cook, in press) based on their efforts to make Logo part of their classrooms. Their experiences while attempting to follow the radical child-centered approach advocated by Papert suggests that, in the case of complex symbol systems, the educational activity must be guided by more mature members of the culture.

When an activity is made functional from the teachers' point of view, the children's activity may change. Those who follow Papert's child-centered approach fear that the activity will lose its intrinsic motivation once teachers decide they want to teach programming. This should not be the case if the teacher's role is to guide rather than impose the activity. However, important changes can result when the activity becomes part of the children's schoolwork. For example, children were often observed to work cooperatively while doing Logo. The children's interviews indicated that the relatively high level of cooperative work was a result of the activity's not being seen as part of the official schoolwork (Hawkins, 1983). There is some concern that, even in Bank Street classrooms where a high value is placed on cooperation, children will be less cooperative when the activity is no longer perceived as play and they have to be accountable to a teacher. FLEs must be functional for both teachers and children for education to happen. The coordination and optimization of these functions, however, remains a difficult issue that demands the attention of educators.

Simulating a Function: "The Science Show"

Another illustration of the importance of the teacher in the structuring of a FLE is found in Bank Street's Project in Mathematics and

Science Education. Materials developed by the project include a television series, software simulations, and workbooks, all of which emphasize the process and tools of scientific work. I will focus on one aspect of the project in which a FLE is based on a multimedia simulation of a navigation problem. While the content is more specific than is the case with Logo, the use of the content is still conditioned by the teacher's interpretation of its function.

A television series, "The Voyage of the Mimi," tells the story of an expedition to study whales off the New England coast. A group of scientists and their teenaged research assistants charter a schooner captained by an old sailor. Although the boat is old-fashioned, it is equipped with electronic navigation equipment, as well as computers and other sophisticated scientific gear. Thirteen episodes take the expedition through a series of adventures in which the crew learns a lot about the sea, whales, navigation, survival in the wilderness, and each other. In one episode, a bad electrical connection causes several instruments to malfunction. The captain suspects that they have been moving faster than his knotmeter indicates, so he has one of the assistants use the battery-operated radio direction finder to establish their position. The assistant calls down the compass bearings for two beacons while the captain plots the position of the boat on the chart. He finds they are actually much closer to dangerous shoals than he had thought. This episode illustrates a functional environment for navigational equipment, as well as for geometry-related skills concerned with intersecting lines and measurement of angles.

A simulation created as part of this project engages the same skills in a similar FLE. The game Rescue Mission simulates a navigational problem in which the players must determine their own position using a simulated radio direction finder, locate the position of a ship in distress using chart coordinates, and then plot a course toward the ship. A simulated radar screen, binoculars, and compass are also available to indicate the current location of the ship. Children play in teams, each attempting to be the first to get to the distressed ship.

The episode described above was designed to show how navigational instruments and geometrical concepts function in a real problem. It engaged children's interest both because they could identify with the teenaged characters and because of the emotional and dramatic tension of the narrative. The Rescue Mission game builds on the understanding of navigational instruments, and adds the motivation of peer interaction and the fantasy goal of rescue. Together with the print materials--workbooks and study guides to be used in the classroom--the show and software provide the basis for FLEs for a number of school-relevant subjects. However, as we saw with Logo, the teacher plays an important role in determining the nature of the software experience.

Char (1983; Char, Hawkins, Wootten, Sheingold & Roberts, 1983) carried out formative research to guide the design of the classroom materials. Working in fourth, fifth, and sixth grade classrooms, she observed the way the teachers used the materials and the children's responses to them. From the children's point of view, the materials were a success. They enjoyed the TV show and were excited by the software simulation. Interviews of the children showed that, after seeing the show and playing the Rescue Mission game, most of them understood the function of the navigational tools and the concepts of plotting positions at the level needed to win the game.

From the teachers' point of view, the results were mixed. The teachers in the study represented a wide range of expertise in their own science and mathematics training and in their use of classroom microcomputers. These teacher differences in training and computer expertise appeared to lead to differences in their interest in and perceptions of the Rescue Mission simulation. Some considered it limited to the function of teaching about navigation, while others found a variety of uses for it across the whole elementary curriculum. For the latter, the simulation and the navigation unit functioned as a jumping-off place for teaching about geometry, mathematical measurement, estimation, the history of the whaling industry, geography, and literature.

Interestingly, it was the teachers less familiar with computers and the teachers responsible for a wider variety of subjects (i.e., those who taught more than math or science) who found Rescue Mission most useful. In contrast, the science and math specialists, who were also more familiar with computers, were less receptive to the game's long-term use. Char (1983) points out that these teachers used computers primarily for programming instruction and were not accustomed to software that presented specific content. Perhaps as a result, the navigational content seemed to them to comprise the primary educational function of the software. Thus, an important finding from the formative research was the need to make explicit the full educational potential of the simulation to those teachers familiar with computers, as well as to those who are computer-naive.

The formative research on the science show materials clearly indicates the extent to which teachers shape children's exposure to materials through the FLEs they set up. It is not sufficient for software developers to create activities that embed important educational facts and concepts. A computer program per se constitutes a very limited FLE. The program must be interpreted by a user or teacher who understands its significance for a variety of culturally important contexts. Like any tool, a program is most useful in the hands of someone who knows how it can be used.

The Functions of Networking for Children and Teachers

The third project that will help to illustrate the coordination of teachers' and children's goals in FLEs is one that has just begun at Bank Street. However, we can draw on the experience of researchers Margaret Riel and James A. Levin of the University of California, San Diego (USCD) for examples of how networking can function as a FLE. Networking is a general term for communications systems that link up computers. Most microcomputers, when enhanced with a piece of hardware known as a modem, can send and receive messages, text, and even programs to and from other computers over phone lines. Networking is becoming a popular pastime among young computer users who call up computerized bulletin board systems (BBSs) to read messages from other people, leave messages about topics of interest, and exchange software.

We at Bank Street are interested in finding out if networking can be used as a FLE for writing and communication skills. Can we take advantage of children's strong motivation to communicate with their peers to create environments in which children can practice writing and learn to write better? An experimental FLE at UCSD gives reason to be optimistic. The Computer Chronicles (Riel, 1983) operated between schools in San Diego and Alaska, several of which were located in isolated areas. Children wrote news stories using a word processor, which were then sent to the other participating classrooms. In each site, the children, with their teachers' help, composed a monthly newspaper drawing on both local stories and those coming from distant places. In many cases, children edited the stories that came in "over the wire" just as newspaper reporters would do. In fact, the frequency of editing someone else's work for style and meaning using the word processor was much higher than is often the case when children write their own stories using the same technology (Quinsaat, Levin, Boruta & Newman, 1983). Thus, the production of a newspaper became a FLE that not only encouraged children to write, but also provided a context for the editing and revision of their own work as well as the writing of others.

The Computer Chronicles shows the potential for networking as the basis for a FLE. It also illustrates a feature of FLEs that have been suggested as important by our other examples: the coordination of the goals of children and teachers. From the children's point of view, the activity was interesting because they were able to communicate with peers who lived in interesting and exotic places (Alaska and southern California, depending on your point of view). From the teachers' point of view, the activity provided a context in which children could practice writing and were motivated to edit and revise their work. These goals are not identical, but neither are they in conflict. It was because the teachers wanted an activity that would encourage writing and revision that they set up the newswire idea, thus giving the children a chance to communicate with interesting peers. However, without the specific structuring, it is unlikely that the children would have engaged in editing each other's writing.

Conclusion

Three examples of FLEs have illustrated the importance of the teacher in creating and interpreting children's learning environments. While, computer software can play an important role in FLEs as a tool, they should not be expected to carry the whole burden of education. Teachers are needed in order to interpret the tools in terms of classroom goals and the larger culture outside of school. Our examples have all been drawn from elementary schools where the need is especially clear. We suspect that, as children develop, the role of the teacher as interpreter or as someone to present another side of the story is gradually internalized, with the result that the mature college student can be expected to use books and manuals to discover multiple points of view on many subjects. Yet, even mature students require the insights of experts when the subject matter is particularly complex.

Our focus on the teacher is not meant to detract from a concern for the children's point of view. Obviously, a FLE cannot work unless it makes contact with the children's interests and experiences. A well-designed FLE is one that coordinates children's and teachers' points of view so that both the children and the teachers can achieve meaningful goals.

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