Schools can adopt computer technology without making any changes in their goals or organization. Or, as Mr. Newman shows, technology can be a catalyst in the creation of new structures for learning.

BY DENIS NEWMAN

School restructuring is currently a focus of many reform efforts that recognize that improving education requires changes in governance, modes of teacher/student interaction, incentives, and methods of evaluation. The roles played by technology in schools and school restructuring are very much a matter of debate. While it has been common for technologists to paint scenarios in which schools are transformed by technology, other analysts of school change argue that technology will not penetrate beyond the margins of the school system. By contrast, Allan Collins has argued in the *Kappan* that the rapidly growing role of technology in the workplace will drive the adoption of technology in schools and spur collateral changes, including a shift from lecturing to coaching and from a competitive to a cooperative social structure. Both positions assume that technology and current practices are to some degree incompatible, an assumption that oversimplifies the poten-

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tial impact of the adoption of technology. Much of the widespread implementation of computer technologies in schools is, in fact, quite compatible with existing structures. To support restructuring, however, technologies must be specifically molded to the task.

I wish to describe a technology environment called Earth Lab that is intended to support a fundamental change in the school – a change away from isolated classrooms, compartmentalized curriculum, and rigid class schedules. I begin with a contrasting case: a class of computer systems that are designed to fit into the existing school structure. The technology design itself does not determine the impact on the school. The contrast is largely in the way the technologies are typically used. The two systems are also contrasts in market success: in one case, there is a rapidly growing industry; in the other, a prototype system is slowly taking hold in just a handful of sites.

SYSTEMS THAT FIT THE CURRENT STRUCTURE

Computer technology is not inherently inconsistent with current school structures. In the past few years, a category of products has emerged that makes it quite easy for schools to acquire and use computer technology without making any major changes in their goals or organization. A report by the Educational Products Information Exchange (EPIE) Institute, an independent organization that provides consumer information, gives a detailed listing of this class of school technology, which is known as integrated learning systems (ILSs) or integrated instructional systems (IISs). These systems typically consist of networked personal computers with a file server that both delivers programs to the individual workstations and keeps records on the progress of individual students. The ILS software (or "courseware") covers most of the school curriculum — thus the term integrated. Systems are sold to school districts at a cost ranging from $60,000 to $180,000 or more for a "lab" of 20 to 30 stations. These systems are growing in popularity, according to the EPIE report, which estimates that sales doubled in 1989.

The EPIE report documents a generally high level of satisfaction with ILSs on the part of teachers and students. The EPIE researchers also note that "teachers want more software options, and (along with students) they want ILS lessons to be more varied and less repetitious in instructional style (or, as students put it, ‘less boring’)." Overwhelmingly, teachers say they would like to have the ILS stations in their own classrooms rather than in a lab so that the work can be better integrated with their curricula. In general, though, ILSs can be considered a successful implementation of computers: one that serves a perceived need and fits in well with the practices of the school. We can examine three prominent features of the use of ILSs: location, curriculum, and the time frame of the ILS tasks.

Location. The EPIE report notes that it is an all but universal practice to put the ILS in a lab. Although there is nothing inherent in the technology that requires this configuration, ILSs are sold as "labs" in units of about 30, which is sufficient to accommodate a whole class simultaneously. Centralizing the ILS in a lab means that the system can be more easily managed by a computer lab teacher or by a nonteaching paraprofessional. For a school starting with a low level of expertise, centralization reduces the training costs that would otherwise be necessary. The vendors’ sales representatives, often recruited from among retired school district superintendents, are expert at addressing management concerns in selling to the district administration.

As the use of these systems evolves, schools may begin distributing workstations among classrooms, and doing so may change some of the prominent features of ILS practice. The number of students who must be assigned to the workstations when they are distributed among the classrooms necessarily favors cooperative work. It may also make it easier for teachers to integrate the computer activities into the rest of their instruction – which, according to EPIE, is a common goal even in the centralized lab situation.

Placing 30 computers in a lab assumes that students will be working at the computers individually, since this arrangement provides for a ratio of 1 to 1. In many ILSs, students also wear headsets as part of their computer interactions, so they are further removed from interaction with their peers. It is argued that the one-to-one instruction that is afforded by having students occupied with computer tutorials offers teachers an opportunity for individualized tutorial dialogues with those students who are often ignored in whole-class teaching. While this change from the traditional style of classroom lectures may be considered a major restructuring of the teacher/student relationship, it is easily accommodated by the curriculum goals, assessment techniques, and class scheduling already in place.

Curriculum. Another feature that fits well with the organizational structure of the typical school is the content organization of the courseware. It is a straightforward matter to categorize courseware into the standard school subjects: math, reading, language arts, or science. This scheme is the same one typically used for textbooks, which are designed to cover the material in a recognized subject area. In fact, ILSs are often explicitly tied to major textbooks. In addition, as in the typical textbook, the content is usually presented as facts or procedures to be mastered in a predetermined sequence. While several ILSs provide such tools as word processors and calculators, the presentation of the courseware is predominantly designed to match the sequence of topics in the textbooks.

The content and its sequencing are integral parts of the management and evaluation functions of an ILS. Discrete tasks that result in a single correct answer can be evaluated by the system itself. Tasks that are more open-ended and require the student to formulate a problem or to consult research sources outside the software and tasks that allow for any kind of free-form response cannot be handled by the system. The sales pitches of those who market ILSs usually focus on achievement gains — especially on standardized tests of basic skills — which find their way into state and national reports of school achievement and for which superintendents must answer to school boards and parents. These claims for achievement gains are used to sell the systems in spite of the doubts expressed by reputable researchers as to their validity. State and federal funds that are targeted for disadvantaged students can often be used to purchase these systems because of the strong relation between the stu-
dents identified for these special programs and low test scores.

The division of topics into clearly defined subject areas also eliminates the need for teachers who are responsible for different subjects to collaborate or for teachers in self-contained classrooms to consider the integration of learning across the subjects. In this respect, too, ILSs strongly support the structure of most schools, in which teachers are not expected to know much about what other teachers are doing. A major advantage of ILSs over other approaches to the use of technology in schools is that teachers can begin using these systems with little technical or subject-matter training and without adopting new styles of teaching or of interacting with other teachers.

**Time frame.** A common complaint of ILS users, according to the EPIE report, is that many systems will not pick up exactly where the student left off in the last session. Tasks are intended to be completed within a single period in the computer lab. Single tasks, such as an arithmetic problem, can usually be done in a matter of a few minutes, but these short tasks may still overlap the end of a period and need to be picked up later.

ILSs are designed on the assumption that each period will be self-contained. The tasks to be done in the computer lab do not require preparation in advance and call for a minimum of technical capability on the part of the student. This design allows an ILS to fit nicely into the usual school structure – divided into periods devoted to discrete topics and, in the upper grades at least, taught by different teachers. Teachers can thus schedule the use of the computer lab into the pre-existing slots in the day. The short tasks of the ILS are also very similar to the kinds of tasks found on standardized tests. The short, carefully constrained answer slots are ideal for automatic scoring in both instances.

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**THE EARTH LAB PROJECT**

For the last six years, the Earth Lab project has been designing, implementing, and observing the effects of a local area network (LAN) system that is intended to facilitate collaborative work in elementary school earth science. Our plan was to create a prototype LAN system and to demonstrate it in a New York City public school using an earth science curriculum. The pedagogical rationale was that students should use technology the way real scientists do: to communicate and share data, i.e., to collaborate.

The Ralph Bunche School is a public elementary school (grades 3 through 6) located in Central Harlem, New York City. The school population of approximately 700 students is predominantly African-American with a minority of Hispanics and members of other groups. The school's scores on achievement tests are about average for New York City. When we began our work at the school, the staff for the most part took a traditional approach to teaching: whole-class lessons, the reading of textbooks, and worksheet drill. Under normal circum-
stances, the school would have been a likely customer for an integrated learning system. However, in this case, the school’s computer teacher, who had a different vision, was able to play a leadership role and make use of the technology provided by the project.

Earth Lab supports restructuring through “decompartmentalizing” instruction. In designing the environment, we assumed that students would benefit from seeing the connections between such topics as math and science or science and writing. Projects that groups of students undertake can be made more authentic — and perhaps more motivating — if they relate to real-world concerns where the boundaries between the disciplines do not necessarily hold. Students can also become more motivated if they are given more control over their own work rather than having it tightly controlled by the school schedule. Classroom tasks may have to extend beyond a single period, because, once students begin working with some autonomy, their projects might involve new goals that are discovered in the process. As students’ projects begin to cross over into different subjects within the curriculum structure, there may well be more collaboration and sharing of expertise among teachers. Evaluation of students may also have to move from the typical short-answer tests of individuals to assessments of group performance on a project.

Our formative experiment began in the fall of 1986, with support from the National Science Foundation. In the initial set-up, a LAN connected the 25 Apple IIe computers in the school to a hard drive that allowed for central storage of data, text, and programs. A word-processing program was enhanced with an electronic mail system. A database management program, another basic tool, enabled students to create databases that could be accessed from any computer in the school. Along with the technology, we introduced a yearlong earth science curriculum designed in collaboration with the teachers.

At least for the one year in which systematic research was funded, we were prepared to modify the design of the technology, to introduce new software, to develop curriculum materials, and to conduct staff development workshops as needed.10 After the first year, the school obtained additional computers through awards from Apple Computer and other sources, and over the last few years it has added a considerable number of Macintosh computers to the network. Several other application programs are now in use on the network, among them, “hypermedia” systems, LogoWriter, telecommunication programs, and Macintosh programs that include desktop publishing tools.

Databases are used extensively both within and outside the earth science curriculum. During the lunch hour, students can be found inventing databases of their favorite action figures. In social studies, students research almanacs and other sources to fill in databases about countries of the world and figures from Afri-
and the computer lab is increasingly used by several projects or groups from different classes working simultaneously. This restructuring supports both individual and group work and contributes to a sense of community in the school. The following examples, presented in the same categories as those used to describe ILSs are taken from our observations at the school and illustrate the impact of these changes.

**Location.** From an initial 25 computers, the school’s network has grown to a total of about 75 in two separate labs and distributed among many classrooms. When teachers bring their classes to the computer lab, they stay with their students rather than hand them over to the computer teacher. The computer teacher works with the classroom teacher to develop activities that can be continued when the students return to their classroom. The project workplaces help groups and individuals develop a sense of continuity that is not possible with the isolated activities of ILSs. The following stories illustrate some of the ways this change has worked.

We expected that projects would be started while the class was in the computer lab and would be continued in the classroom. However, we found that the students were taking this flexibility one step further. For example, we observed two girls working on a book report at a computer in a small room off their classroom. When the teacher announced that it was time for the class to go upstairs to the computer lab, the girls had not finished their work. Instead of dropping it, they simply brought their notes with them and asked if they could continue their work at a lab computer while the rest of the class worked on other assignments. The students logged on and called up the file on which they had been working. The network makes the boundaries between classrooms and class periods more permeable. This permeability was used by these and other students to pursue tasks on their own initiative.

Several students from different classes and grades were editors for the school newspaper. The newspaper had a workplace on the network that students used for storing articles and other material for the newspaper. Beyond the editorial group, many students around the school contributed articles to the newspaper by sending them to the editors as messages through the electronic mail system. The common workplace made it easy for the editorial group to work on the newspaper at different times and places. The ease with which any student could contribute to the newspaper widened participation. Students became familiar with the network’s function as a data organizer so that when other school projects, such as editing a video newscast, were started, the students thought it quite sensible to create a workplace for their scripts, plans, and edit lists.

Activities in the computer labs are very heterogeneous. Although the labs, housed in adjacent rooms, have enough computers to accommodate a class with each student using a computer individually, we seldom see the computers used in this way. Usually students work in pairs or in small groups. Since there are spare computers, students from other classes and teachers during their preparation periods also come to the lab to work on various projects.

Groups of students frequently work with more than one computer simultaneously. For example, a group of students was using a word processor to compose a letter to students in Australia with whom they had been telecommunicating. One student suggested that they include some of the data from their math project in their letter. A second student turned to an unused computer at the next desk. She called up the database manager, compiled a report of the required data, and saved it to the group workplace on the network, where it was merged into the letter the group was preparing. The letter complete, it was mailed on the LAN to the person responsible for sending it to Australia. It was possible for the students to create a “multitasking system” out of the two linked computers because they knew where one computer had to save the data so that the other computer
could find it. For students accustomed to sharing data on the network, the method was obvious.

The fact that the “tool” applications (as opposed to content-specific games or drills) are used heavily makes group and individual projects the appropriate mode of computer use. The Earth Lab interface, which displays for students and teachers lists of their project workplaces, enables them to work on any of their projects at any time and from any of the networked machines available to them. With this greater flexibility and the continuity over space and time, students can take more initiative in following through with work on a project.

Curriculum. The earth science curriculum developed for the initial field test and the curriculum materials that the teachers have continued to develop over subsequent years have been interdisciplinary. As they worked on weather and seasonal change, students made connections to physics, math, writing, and social studies. The network system made classroom projects easier to manage and promoted collaboration among the teachers.

We observed substantial movement from whole-class teaching toward more collaborative work in small groups. We found, for example, that the science groups that had been formed to work together in the science lab were being used by the classroom teachers for a variety of social studies research activities, some of which were unrelated to the earth science curriculum. The network system produced these changes in an unexpected way: it made it possible for all teachers to assign classroom work to the groups created by the science teacher. The workplaces for the science groups were a convenient means of organizing small-group projects in other curriculum areas. Thus the science groups became a resource across the school. There had never been a mechanism in this school by which a social organization created by one teacher could be used by other teachers as a resource for managing instruction. 11

At the beginning of the formative experiment some teachers in this essentially traditionally school had doubts about the students’ capabilities for handling the autonomy involved in small-group work. Having the small-group workplaces on the network helped communicate to the teachers that students were expected to do collaborative work. When interdisciplinary projects become a more common feature of the curriculum, the workplaces can give the students a clearer group identity and sense of project continuity and thus help in classroom management. Instead of giving the teacher greater centralized control of individualized instruction, as is common in integrated learning systems, the network allows control to be distributed to the students. We suspect that the solution to teachers’ difficulties in managing instruction involving collaboration among students is to provide the tools with which the students can assume some of the burden rather than to provide teachers with tools with which to gain greater control.

But students are not simply going off to work on their own projects without regard to any of the curricular goals of the teachers. The network also makes it easier for the teachers to appropriate the output of the small groups and use it for whole-class activities. Thus work can go back and forth between individuals and groups and larger integrative projects that combine the work of groups.

The LAN technology seemed naturally to invite coordination in which students contribute to some larger quest for knowledge, since it was easier to give common access to the same shared data than to maintain separate copies for each individual or group. 12 Our project on the collection of weather data provides a good illustration. The data, which had been collected throughout the school year by a rotating group of students using a small rooftop weather station, were entered into a database in a shared workplace. The database was later used to discover correlations between such variables as pressure and cloudiness. The whole data set became the object of group discussion of relationships that could not have been discovered through individual contributions. This coordination around a shared database was a new kind of activity that emerged because of the LAN technology.

The Earth Lab network made no attempt to provide a technological solution to the problem of assessing student progress or grading student projects, which is a central function of integrated learning systems. However, we have begun to explore the use of group and individual workplaces as portfolios of student work. The notion of a portfolio is receiving growing attention from educators as an alternative means of assessment in which the stages of a student’s work on a project can be gathered in one place to provide insight to both the teacher and the student about the state of the work and about the process of learning. The workplaces currently serve as archives of group or individual project work and so can function as portfolios.

Time frame. The project workplaces provide continuity of time as well as of location. Projects involving the collection of weather data and data on seasonal change extended over many months. In some cases, projects may extend over years as new groups of students move through the school. The continuity over time that is developing in the school may have an important impact on what students are able to do as they gain technical skills with the computer tools available for their project work. The following examples suggest the nature of this impact.

One science group was analyzing the weather data using the database manager. They were trying to support a theory suggested by their impression that the last winter had been much milder than the previous one. They compared their data with that collected by the previous year’s sixth-grade class. When their theory was not supported by averages in the report generated with the database program, one of the students checked the data as entered by classmates. Several temperatures
seemed unrealistic – e.g., several January days with highs of zero degrees. Suspecting an error attributable to missing values, they sent electronic messages to representatives of several other classes that had kept similar records and obtained new data for the days in question.

Many students used the computer system extensively for their own projects – apart from any assigned work. Much of the student-initiated work was carried out during lunch hour and after school, when the computer lab remained open. Students were able to pursue their own writing, data collection, or programming projects. While some educational games were also available during these extra periods, many students chose to pursue serious projects rather than to play games. The students developed a sense of ownership of their workplaces to a greater extent than we had anticipated, and some students accumulated hundreds of files in their workplaces over the course of a year. Furthermore, students retain the same personal workplace from year to year, so work done in one year is not lost when they move to the next grade.

Earth Lab was also used for student-initiated collaborative work. For example, many science fair projects, which were a source of great pride for students, were monitored, analyzed, and documented on the system. The students’ appropriation of the technology was also evident in end-of-the-year interviews. For example, one student suggested that the system should be adapted to enable students to determine who could have access to a workplace, because she did not have easy access to work she was doing with another student. Taking her suggestion one step further, our current implementation design will make it easy for students to create their own new workplaces for specific projects, as well as to determine who will be able to use the files in those workplaces.

The use of tool software requires a greater initial investment of time in order to bring students up to speed with the technology than is required for integrated learning systems, which present small tasks and simple interactions with the technology. However, the availability of the Earth Lab system to students over a period of years and the consistency of the available tools have made it increasingly easy for teachers to introduce long-term projects as part of their curriculum. In the first year of operation, the sixth-grade class spent several months on fairly simple introductory projects designed to familiarize them with the word-processing, database, and communication tools. Several years later, teachers are able to start immediately with substantial projects.

For the first few years, students entered sixth grade with widely varying levels of expertise because of the uneven use of the technology among the fifth-grade teachers. However, enough students had the necessary knowledge to help get projects off the ground. In one case, the class began early in the year to collect data on the length of their shadows. Students who were familiar with the database manager entered all the data into a database, which was then available for all the students to explore. Students who were unfamiliar with the tool were introduced to it in the context of substantial data that they had helped to collect.

The school in which Earth Lab has been operating for six years has been restructured with the creation of a school-within-a-school that focuses on an experiment in teacher collaboration. Approximately one-fifth of the students signed up for a “computer minischool” that now involves eight classrooms and spans grades 4 through 6. A portion of the school’s computer technology serves this minischool in the ways that have been illustrated.

Teachers voluntarily gave up contractually guaranteed free periods in exchange for remediation and enrichment more effectively by bringing those services to the classrooms rather than fragmenting the students’ day with pull-out programs.

The classrooms are heterogeneously grouped with respect to achievement. There is no shortage of volunteers for the minischool from any of the achievement levels found in the school. Each year, new students are selected by lottery for the fourth-grade slots, and the program is expanding slowly to additional classes in each grade. The choice of forming the minischool from a sequence of grades is important for developing continuity over a long period and for building the skills and expectations of students and teachers. The sixth-grade teachers are continually challenged by the growing skills of their incoming classes.

Students in the computer minischool consistently outscore students in the rest of the school in achievement tests given by the city, a fact that has guaranteed district support for the experiment into its third year. Technology can take only indirect credit for improving student achievement since the minischool did not use any drill-and-practice software geared to improving test scores. The teachers attribute the change to the greater sense of stability and community in the minischool. The technology was one of many factors supporting that sense of community.

SUMMARY

One common theme runs through these observations: students have a place in the computer system – their individual and group workplaces containing their project data – that does not depend on having an individual computer or being in a particular classroom. These workplaces enable students and teachers to cross boundaries between school contexts. The extent to which students and teachers used the system for their own work gives us reason to believe that systems such as Earth Lab can be sustained in the schools.

The system that we installed in the school was to some extent modeled on the use of technology in research labs, but the system that emerged had characteristics quite specific to schools: the coordination of small groups, the teacher collaboration, and the use of work-
places rather than personal workstations. Our formative experiment succeeded in using technology to increase the likelihood that collaborative work groups would be used, but we also discovered that a critical function of LAN technology in schools is to make a more seamless connection between school contexts. In this respect, we found ourselves focusing more on the level of the school organization and the collaboration among teachers than on the students working collaboratively around a computer.

In this article, I have contrasted two very different uses of computer technology in schools and attempted to trace their relationship to the way the school organizes instruction, the way teachers work together, and the opportunities students have for engaging in long-term, open-ended projects. The relationship between technology and the organization of instruction is complex. An integrated learning system certainly does not cause a school to have a compartmentalized curriculum and a division of labor among teachers. It may, however, provide strong support for those tendencies and place barriers in the path of teachers who may wish to change their way of teaching. At the same time the use of these systems can be modified quite radically by, for example, distributing the computers among the classrooms, where they might become more integrated with ongoing work. In the same way, a system such as Earth Lab does not cause collaborative, interdisciplinary project work to happen. But for schools that are moving in that direction, it can provide some useful tools and mechanisms.

In planning a replication of the Earth Lab environment in other schools, we face the complex relationship between the technology system and the existing structure of instruction in the schools. When schools acquire technology, the typical approach is to purchase a new “lab” – even when the technology is to be devoted to word processing or programming or earth science projects. The lab becomes the convenient unit for administering the new computers and for “selling the idea” to the administrators who will make the decision.

From a purely administrative point of view, the people in charge of technology acquisition often have no authority over school structure, so they necessarily accommodate the technology to the existing structure. The restructuring that the computer minischool is engaged in cannot be provided to the school as a “package.” The flexibility of location and time, the collaboratively constructed interdisciplinary curriculum, and the provision for student access to the tools over an extended period are critical components of this environment. However, the design of a LAN system, such as that used in Earth Lab, can slowly subvert a rigid structure by supporting teachers and students in their effort to explore new ways of learning.

5. Ibid., p. 295.
12. Ibid.

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