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PUBLIC ACCESS TO PERSONAL COMPUTING: A NEW ROLE FOR SCIENCE MUSEUMS

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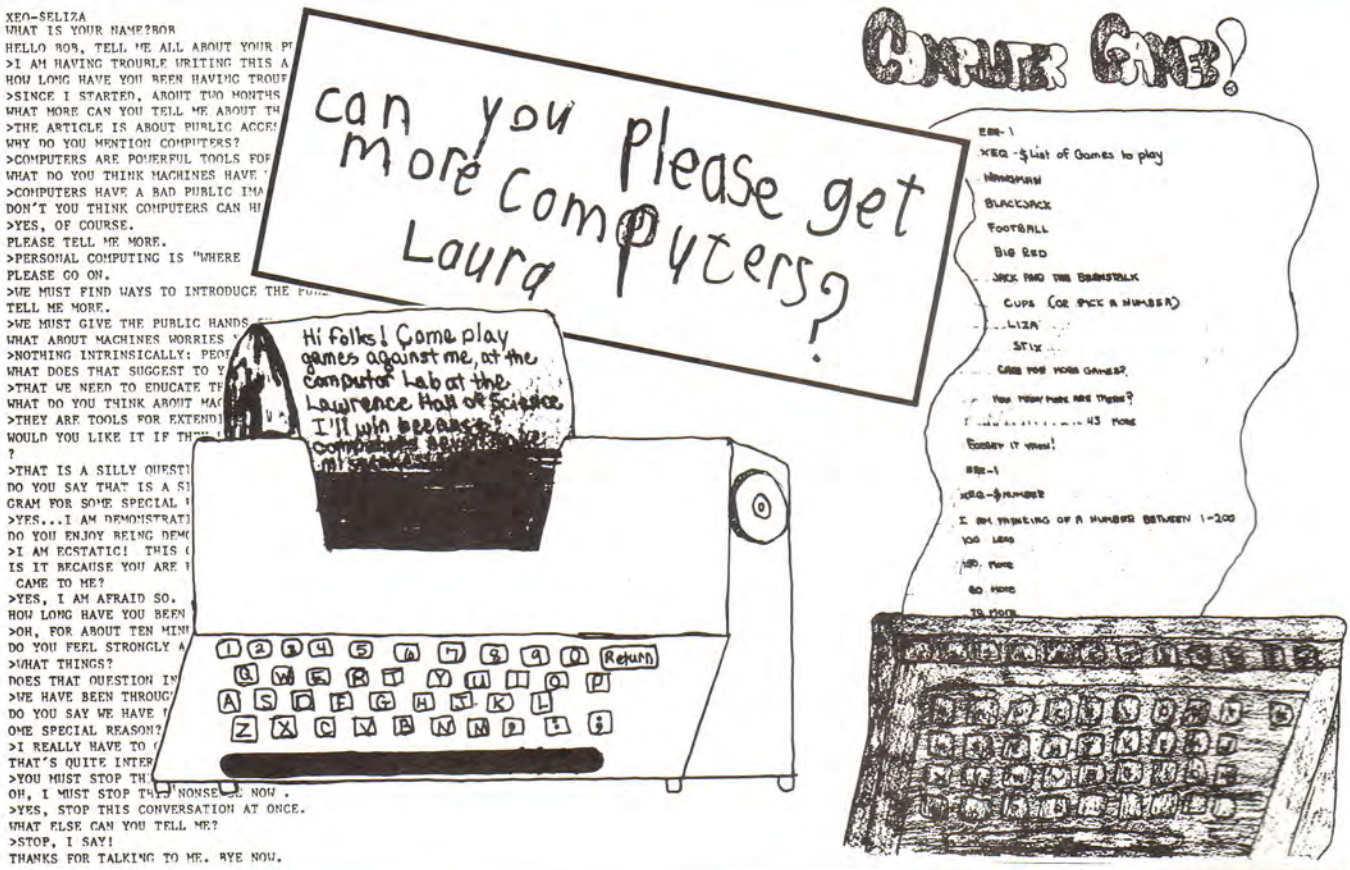

Public Access to Personal Computing: A New Role for Science Museums

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Museums and computers

From an educational standpoint, science museums and computers have shared a common characteristic: both have tended to be static and passive, offering little opportunity for participation in or access to technology. A museum visit, always a culturally respectable way to spend a Saturday afternoon, generally involves a lot of walking, looking, and listening, but little touching or participating. Likewise, public access to computers has generally been vicarious, or limited to computer output only. We watch the airline ticket agent make a reservation at the terminal, we receive computer-generated form letters and bills in the mail, and we peer through the glass portal at the computerized San Francisco Bay Area Rapid Transit Control Room.

But all that is changing. Science-technology centers are redefining their traditional role. No longer are they merely a community showcase and repository; they are making modern computers accessible and understandable to the general public.[12] Instead of rows of glass cases protected by signs and security guards, modern science centers encourage visitors to touch objects, manipulate controls, and participate in workshops and classes in an informal, non-school museum environment. Clearly, interactive computers and computer terminals would be right at home in such places. Indeed, most science-technology centers recently built or still in the planning stages have made provisions for computer-related exhibits and activities. However, few of the older centers (let alone science museums) have made computing accessible to the public, although many have expressed interest in doing so. Unfortunately, bringing about change in established institutions, even institutions which are concerned with the latest technology, can be a slow, difficult, and expensive undertaking.

Levels	*Characteristics*	*Examples*
LEVEL IV: Ideal Public Access Computing Center	Basic Research on the Person-Computer Interaction Development of New Personal and Public Uses of Computers Community Program Library and Data Bank Publicly Accessible Showcase for Newest Technology Development and Dissemination of Educational Computer Programs, Resource for Personal & Home Computing Needs	
LEVEL III: Active Community Computer Education	Community Computer Education Resource and Time-Sharing Service Range of Classes for Children & Adults Many Terminals Located in Exhibit Area & Computer Terminal Rooms (Pay by the Hour) Use Library Programs or Write Own Programs	Lawrence Hall of Science
LEVEL II: General Public Access	Educational Computing Resource Center Applications Programs Written & Distributed On-Site Computer & Computer Specialist 1 or More Interactive Terminals in Exhibit Area with Repertory of Programs, Games, Information, etc.	The Boston Children's Museum Oregon Museum of Science & Ind. Boston Museum of Science Maryland Academy of Sciences Ontario Science Centre Pacific Science Center
LEVEL I: Special Public Access	A Programming Class for Local Kids School Field Trips and/or Special Classes, Workshops & Demonstrations for School Children, ages 6-18 One or More Computerized Exhibits Special Kids in the Basement	Franklin Institute Science Museum & Planetarium California Museum of Science & Ind. Chicago Museum of Science & Ind. Fernbank Science Center
GROUND LEVEL: Potential Public Access	Research, Data Processing, Cataloging and Record-keeping, Visitor Scheduling, and Controlling Equipment	A Majority of Science-Technology Centers and Museums

Figure 1. A model of public access to computers through science-technology centers and museums.

Public access to computing through science-technology centers

Early in 1976, the Association of Science-Technology Centers published a survey of educational programs at its member institutions.[7] Of the 54 centers surveyed, 27 returned the questionnaire, and of that 27, only 10 institutions had one or more computer terminals.* Figure 1 describes the involvement of these institutions in making the public aware of the potential of computers. The model contains five levels and is stratified so that each higher level usually includes all those levels below it as well, and most—if not all—science-technology centers and museums may be located on an appropriate level. The various levels of the model are described moving from minimal public involvement at the bottom to potentially attainable involvement at the top, citing examples of institutions whose programs are particularly exemplary within various levels.

* Because only half of the ASTC members responded to the survey and because some institutions having a substantial computer component such as the Boston Children's Museum are not members of ASTC, these summary statistics and the profiles which follow must be viewed as exemplary rather than as exhaustive. While I have no doubt that the activities and programs described are quite representative of the status quo, I may well have omitted some institutions having similar, or even more extensive, computer-related programs.

Starting at the bottom of the model in Figure 1, the ground level or "lowest common denominator" for computer use in science centers and museums is research, data processing, cataloging and record-keeping, visitor scheduling, and controlling equipment such as the museum's planetarium. Like other businesses, museums have information processing needs. Thus, when a museum or science center acquires a computer or computer services, this is often one of the first (and sometimes the only) application to be realized.

In a sense, this level does not belong in the model; our concern here is with public access to computing and not just with the ways in which these institutions make use of computing power. However, an institution that is using computers for its own business needs can begin to explore ways to make computing available to the public. Therefore, this might better be called the seed level of the model; once an institution acquires some access to computing power, it has the option to decide to what extent this power will in turn be accessible to the public.

A museum that builds a glass case around the computer for the public to watch the machine at work rather than interacting with it is reinforcing the mass-media image of computers. This is not really a commitment to public computer access. In such cases, it might be better to keep the machine hidden and say nothing

Last year over 3000 children made one-time visits to the Community Computer Center and 500 others attended continuing classes at the center. Above, teacher-director Joanne Verplank conducts get-acquainted sessions on the computer with visiting students. Below, children soon learn to operate the terminals themselves.

Profile of a Storefront Computer Center

The Community Computer Center, in a storefront in suburban Menlo Park, California, is a place where people and computers get together. A non-profit corporation, the center provides public access computing and teaches classes on and about computers — mostly to children on school field trips.

The center was originally a branch of the People's Computer Company, itself a sort of free-form non-profit corporation started in 1973 by Bob Albrecht, Mary Jo McPhee, and LeRoy Finkel — all former programmers. (People's Computer Company still exists — printing a newspaper by the same name and operating a mail-order bookstore.)

Two full-time staffers — Doug Faunt, who keeps the PDP-11/15 operational and teaches classes in both hardware and programming, and Joanne Verplank, who serves as teacher director — keep the place going. Faunt is a computer engineer formerly with ESL; Verplank is a former elementary school teacher with a degree in psychology.

Although it originally depended heavily on volunteer effort, the center is basically self-supporting today, with revenues coming principally from field-trip fees and class tuitions. A grant-loan of $500 from the Peninsula ACM chapter funded a hardware lab, and a gift of $6400 from the San Mateo Foundation, a local philanthropic organization, has provided scholarships for a portion of the 3000 children who visit the center on one-time field trips. Some 500 children attend continuing classes.

Revenues from a fund-raising book entitled *What to Do After You Hit Return,* plus donations and a bank loan, helped buy a PDP-11/15 in January of 1976. This has enabled the CCC to offer schools the option of renting a teacher (Verplank) along with a video terminal for a day or two. Using the terminal, the teacher can dial into the center's PDP-11/15 and expose several classes of students to the possibilities of computers.

Future projects at the center include bringing computer recreation to hospitals and nursing homes by training a cadre of senior citizens to operate portable terminals and teach computer games to shut-ins. Plans are also under way to extend the CCC's work with schools to include workshops for teachers and install multiple dial-up lines that will allow the schools to access the PDP-11/15 and conduct their own programming and games sessions.

Those interested in learning more about the CCC can write Ms. Verplank directly at the Community Computer Center, 1919 Menalto, Menlo Park, CA 94025.

"Game Nights" at the Community Computer Center give the public a chance to learn about computers, play games, or do homework. Mostly it is a family-type activity.

of its existence. Instead, an institution must begin to exhibit its computing power in such a way that the general public may not only watch the machine work, but also work (play) with the machine. Indeed, an institution that is truly committed to educating the public about computers and their use obtains a computer specifically and primarily for this purpose. Such an institution treats administrative data processing and record-keeping as a separate aspect, or even a side benefit, rather than as the main justification for having a computer. This latter philosophy becomes increasingly more dominant as we move to each higher level in the model.

Level I: special public access

Special kids in the basement. Once a public institution has acquired a computer, it is difficult to keep the machine a secret. Neighborhood children (young and old) always seem to start coming around to check out the equipment and find out how, why, and when the machine is being used—and by whom. Some of these interested people turn up frequently, and sooner or later, they seem to acquire privileges, perhaps in exchange for programming services rendered, whether solicited or not. (Some of them are occasionally given long-term projects in exchange for peace of mind on the part of whoever is in charge of the machine.)

Some institutions, such as the University of California's Lawrence Hall of Science (LHS) in Berkeley and the Oregon Museum of Science and Industry (OMSI) in Portland, have developed special programs for these "special kids." For several years, Pete Rowe, the senior applications programmer at the Lawrence Hall has been offering a "free" (i.e., no tuition charge) class to local students who have become proficient in programming and who have a useful and interesting programming project they wish to complete. To be admitted to the class, students must submit a written proposal outlining the nature and goals of their project. Students whose proposals have been accepted gain specially arranged computer access on Friday afternoons and space-available access at other times during the week. Several of these students have been hired by LHS to write applications and systems programs and some, upon entering Berkeley as freshmen, have joined the staff of the LHS Computer Education Project.

Similarly, OMSI's Community Research Center provides about 40 students per year an opportunity to carry out independent science research projects using the museum's PDP 11/45 computer. This is a more formal research training program for which there is a tuition fee, and in which more concentrated access to the computer laboratory and staff is provided. Here again, acceptance into the program is based on the quality of a student-initiated proposal. In addition to high school credit, many of these students have earned awards and college scholarships as a result of their work.

Special classes and school field trips. The remainder of the first level is composed of organized groups of visiting school children. One large educational activity of all science-technology centers and of most museums is providing demonstrations, classes, and field trip programs for school children. While these children represent an extremely large group compared to the "special kids," they are still a specially selected group, and their access to the institution—and thus to the computer—is strictly controlled. Furthermore, at this level of the model, the computer is only available when a staff member of the institution is present to offer a scheduled class or workshop. Thus, even if children who learned something about the computer during a school field trip were to return to a "Level I" institution on a weekend, for example, the computer would not necessarily be available for further individual exploration.

Programs and activities offered by science centers for visiting school children vary considerably, depending on the size of the institution, its staff, and especially on the computer facilities available. The California Museum of Science and Industry in Los Angeles, the Franklin Institute in Philadelphia, and the Fernbank Science Center in Atlanta are examples of institutions having restricted computer access as described above. The following three examples are taken from institutions at all levels so as to describe more adequately the range of computer activities available to visiting school children. Notice the dramatic difference in field trip programs at institutions further up the ladder from Level I.

At both the California Museum of Science and Industry in Los Angeles and the Franklin Institute in Philadelphia, one APL terminal connected to a remote IBM 360 (with the terminal and/or computer time subsidized by IBM) is used in group demonstrations of up to 50 children at a time. This is accomplished by seating the children amphitheater-style around the terminal and using a closed circuit television camera and monitor to give a close-up view of the action to the entire group. A museum staff member runs the demonstration, making use of as many volunteer student "assistants" as possible. Using the APL language, the museum instructor demonstrates the machine's ability to do various arithmetic computations, formula evaluations, information storage and retrieval, a form letter, and perhaps some games or typewriter pictures and posters.[9] (Similar demonstrations are sometimes offered to the public at a few announced times on weekends.)

The Children's Museum in Boston, on the other hand, has five CRT terminals (connected to its PDP 11/40 computer) and several Wang calculators located in one corner of its visitor center. The CPU console, with its switch register (all switches disabled) and flashing lights also faces into this computer corner. Rather than attending formal demonstrations or workshops on computers, visiting school children are simply free to play with the calculators, press the CPU switches, and explore the various games offered on these terminals—at their own pace and on their own initiative.[5]

The Lawrence Hall of Science, with its two computer classrooms, each containing 10 Teletypes (connected to a Nova 800-based timesharing system), combines both of these approaches. Organized, staffed workshops are offered to groups of up to 30 visiting school children at a time. A brief introduction to computers is given to the visiting students by a staff member of the LHS Computer Education Project (these staff members are all college students at Berkeley and work part time for the project). Then the students spend an hour, in groups of two or three per terminal, exploring a variety of games and simulations from the LHS program library while the LHS staff member circulates around the room, answering questions and helping students who have difficulties. Lawrence Hall also has computer terminals located in its exhibit area, so these students may interact further with computer terminals during any time that they are allowed free exploration of the exhibits.

To summarize, this is the nature of Level I, Special Access: either a very few special children learn a great deal about computers or a great many children have a very brief introduction, often with no avenue for follow-up. Because so little data are available on the current

state of computing activities and science centers and museums, it is difficult to determine how many institutions besides Los Angeles, Philadelphia, and Atlanta would best be classified at this level. It is certain that Ground Level and Level I, together, best describe the current state of public access to computing at a majority of science centers and museums in the nation.

However, this model places more value on programs that encourage follow-up opportunities so that once people have become more interested in computers, they will have an opportunity to learn more about them and they will have a place where they can go to use them. Also, the model is based on access for the *general public,* which includes adults as well as children, and a broad spectrum of people rather than selected groups. Levels II and III show a definite step forward in regard to both of these points.

Level II: general public access

Public fascination and museum commitment: a scenario. On any given weekend, one may walk into any of the institutions listed in Levels II and III of Figure 1 and observe roughly the same phenomenon: a group of involved, happy, energetic children *and some adults* huddled around the computer terminal(s) . . . usually playing games.

Furthermore, while most exhibits in a science center are doing well to keep a visitor's attention for more than a minute or two, the computer generally must be programmed to encourage people to let others have a turn after five minutes or so, since visitors have been observed to spend 15-20 minutes or more playing games at computer terminals. And while people tend to browse through exhibits and skim over or even ignore printed text (particularly if there is much of it), most computer terminals in museum exhibits communicate exclusively through text printed on CRT's or various typewriter-like terminals; so, a museum visitor who is spending 15 minutes or more at a terminal must be reading—at least some of the time.

This scenario raises several interesting questions (as yet unanswered) regarding what people learn from playing games with computer terminals. It also points out an important fact—namely, that people are fascinated by the power of interactive computing, particularly when it is presented in an informal, non-threatening, playful environment. Here, then, is evidence that the modern science-technology center is, indeed, an ideal institution for providing *public* access to computers, and in fact, that the computer potentially may be one of the most powerful educational tools in that institution. The realization of this fact and an institution's commitment to finding ways to put the power of computing in the hands of the public—to make computing accessible, understandable, and personal—truly distinguishes institutions at Levels II and III of our model from those at Level I. The Boston Children's Museum provides a good example of such realization and commitment. In a 1972 proposal to the National Science Foundation entitled "Demystifying Computers," Bill Mayhew, coordinator of the museum's computer center, summarized the goals of his proposed project as follows:

> As technology grows in scale and capability, it is the responsibility of society to control it. To facilitate that control, each of us must learn how to deal with technology sensibly, based on facts and not on misconceptions. One of the best ways for people to learn about things is to use them in a way that provides maximum flexibility in a creative atmosphere. In the case of computers, this means placing a variety of computing resources in the hands of the public, along with new and exciting ways to use them.[13]

There are two main ways in which science centers and museums (including the Boston Children's Museum) have implemented Mayhew's goal: (1) by placing computer terminals and/or computer-controlled devices in public exhibit areas and (2) by offering computer classes to the public.

Table 1. Categories and examples of interactive computer games and programs.

CATEGORIES OF COMPUTER GAMES AND PROGRAMS	*SOME POPULAR EXAMPLES*
GAMBLING GAMES AND GAMES OF CHANCE	BLACKJACK, CRAPS, ROULETTE, CUPS
NUMBER GUESSING GAMES	GUESS, STARS, TRAP
WORD GAMES	WORDS, PASSWORD, HANGMAN
NIM-LIKE GAMES	23-MATCHES, SIMNIM, CHOMP
STRATEGY BOARD GAMES	TIC-TAC-TOE, GOMOKU, QUBIC
HUNTING/COORDINATE SYSTEM GAMES	WUMPUS, HURKLE, BATTLESHIP
RULE GAMES AND GAMES OF LOGIC	IN&OUT, BAGELS, REVERSE
CONVERSATIONAL & INSTRUCTIONAL PROGRAMS	ELIZA, QUERY, MATHDRILL
ARTIFICIAL INTELLIGENCE; PROGRAMS THAT LEARN	ANIMALS, ENCYCLOPEDIA, HEX-A-PAWN
INTERGALACTIC WAR AND TRADING GAMES	STARTREK, SPACEWAR, STAR-TRADER
ECONOMIC, SCIENTIFIC, AND SOCIAL SIMULATIONS	STOCKS, KING, GENE I, POLICY, HOME
SPORTING GAMES AND OTHER SIMULATIONS	FOOTBALL, RACETRACK, LUNAR-LANDER
TELETYPEWRITER PICTURES AND PATTERNS	SNOOPY (et al.), AMAZE, POSTER
INFORMATION RETRIEVAL, ELECTRONIC BULLETIN BOARD, DATE, AND CALENDAR PROGRAMS	INFO, NEWS, BIRTHDATE

Computer games for the public. The most common approach to give the public a hands-on introduction to computers is to place one or more interactive terminals in an exhibit area. Visitors are then challenged, implicitly or explicitly, to match wits with the computer by sitting at the terminal and playing a game of one sort or another. Some generic categories of computer games are listed in Table 1, and examples of output from two such programs are shown in Figures 2a and 2b. At least two compilations of computer games have recently been published.[1,15]*

*The reader interested in the social, and educational ramifications of computer games is referred to a 1973 article that appeared in *Infosystems* entitled "Computer Games People Play"[6] and an article by Daniel L. Goldwater, Education Director of the Franklin Institute, entitled "Games People Play—On Computers."[9] Stuart Brand's 1972 *Rolling Stone* article (also reprinted in *II Cybernetic Frontiers)* entitled "Spacewar"[3] gives a good overview of current efforts towards and implications of bringing computers to the people.

Figure 2a. Computing is a family activity at the Lawrence Hall of Science—here father and son, mother and daughter work on home energy usage program.

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XEQ-HOME.A001

WELCOME TO HOME - A HOME ENERGY USEAGE PROGRAM

WHAT IS THE FLOOR AREA (ROUGHLY) OF YOUR HOME (SQ. FT.)? 1500
ARE YOU REASONABLY CERTAIN OF THIS FIGURE? YES
HOW MANY STORIES DOES YOUR HOME HAVE? 1
WHICH OF THE FOLLOWING BEST DESCRIBES THE INSULATION IN YOUR CEILING:
   1)  UNINSULATED
   2)  PARTIAL
   3)  FULL
1,2 OR 3 ? 2
WHICH OF THE FOLLOWING BEST DESCRIBES THE INSULATION IN YOUR WALLS:
   1)  UNINSULATED
   2)  PARTIAL
   3)  FULL
1,2 OR 3 ? 2
DO YOU HAVE A GAS OR ELECTRIC FURNACE? GAS
WHAT DO YOU SET YOUR THERMOSTAT AT DURING THE DAY? 66
WHAT DO YOU SET YOUR THERMOSTAT AT DURING THE NIGHT(0=OFF)? 0
HERE IS A SUMMARY OF WHAT YOUR ANNUAL HOME HEATING ENERGY SHOULD BE:


PART          %ENERGY      THERMS       $ COST/YEAR

CEILING         27          113.68        18.19
WALLS           19          79.9          12.78
WINDOWS         28          120.48        19.28
FLOORS          12          52.84         8.45
INFILTRATION    14          61.84         9.89

TOTAL           100         428.74        68.6

     FOR MORE INFORMATION ABOUT INSULATING YOUR HOME, AND
OTHER ENERGY SAVING MEASURES, CONTACT YOU LOCAL P.G.&E.
OFFICE.  THANK YOU FOR VISITING THIS EXHIBIT.

TEAR OFF AND TAKE THIS PAPER WITH YOU.
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Figure 2b. Computer terminal located in a public exhibit at Lawrence Hall of Science "learns" about animals.

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XEQ-ANIMAL
THINK OF AN ANIMAL.
IF I GUESS WRONG, PLEASE HELP ME WITH A GOOD QUESTION.
ARE YOU THINKING OF AN ANIMAL?YES
DOES IT LIVE IN WATER?NO
DOES IT HAVE WINGS?NO
IS IT A DOMESTIC (HOUSE OR FARM) ANIMAL?NO
DOES IT HAVE 4 LEGS, NO MORE, NO LESS?YES
DOES IT HAVE A LONG NECK?NO
IS YOUR ANIMAL A TIGER
?NO
WHAT IS YOUR ANIMAL?PANDA
GIVE ME A QUESTION I CAN ASK TO TELL A TIGER FROM A PANDA.
THIS QUESTION MUST BE ANSWERED BY YES OR NO.
?IS IT BLACK AND WHITE?
FOR A PANDA YOUR ANSWER IS:(YES OR NO)?YES
THINK OF AN ANIMAL.
IF I GUESS WRONG, PLEASE HELP ME WITH A GOOD QUESTION.
ARE YOU THINKING OF AN ANIMAL?YES
DOES IT LIVE IN WATER?NO
DOES IT HAVE WINGS?NO
IS IT A DOMESTIC (HOUSE OR FARM) ANIMAL?NO
DOES IT HAVE 4 LEGS, NO MORE, NO LESS?YES
DOES IT HAVE A LONG NECK?NO
IS IT BLACK AND WHITE?YES
IS YOUR ANIMAL A PANDA
?NO
WHAT IS YOUR ANIMAL?ZEBRA
GIVE ME A QUESTION I CAN ASK TO TELL A PANDA FROM A ZEBRA.
THIS QUESTION MUST BE ANSWERED BY YES OR NO.
?DOES IT HAVE STRIPES?
FOR A ZEBRA YOUR ANSWER IS:(YES OR NO)?YES
THINK OF AN ANIMAL.
IF I GUESS WRONG, PLEASE HELP ME WITH A GOOD QUESTION.
ARE YOU THINKING OF AN ANIMAL?YES
DOES IT LIVE IN WATER?YES
DOES IT HAVE LEGS (OR FLIPPERS)?NO
DOES IT HAVE FINS?YES
DOES IT HAVE GILLS?NO
IS IT BIGGER THAN THE SIZE OF A CAR?NO
IS YOUR ANIMAL A DOLPHIN
?YES
HEY, GREAT! I GOT IT! THINK OF AN ANIMAL.
IF I GUESS WRONG, PLEASE HELP ME WITH A GOOD QUESTION.
ARE YOU THINKING OF AN ANIMAL?STOP
```

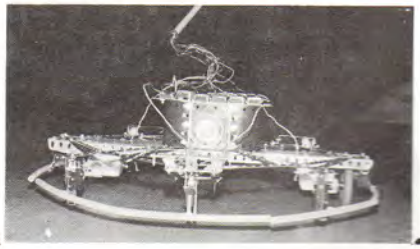
In most science centers, a few games and programs such as those shown in Figure 2 (Table 1), are linked to a monitor program. This monitor program usually provides any or all of the following features:

(1) a menu (i.e., a selection of programs from which to choose);
(2) recordkeeping (e.g., how long which games were played and survey data such as age and sex of the players);
(3) timekeeping (i.e., ensuring turnaround or turn-taking at the terminals);
(4) "public-proofing" of programs (i.e., parsing visitor input so as to recognize and effectively respond to (or ignore) null, extraneous, incomprehensible, random, or obscene input);
(5) "escape-proofing" of progams (i.e., programmatically disabling the Escape or Break keys used to abort program runs). This function may also be accomplished through hardware modifications.

The Honeywell Computer Exhibit at the Boston Museum of Science[16] is a good example of such a monitor program.

Computer-controlled devices for the public. In addition to having public terminals, the Boston Children's Museum, OMSI, LHS, and other institutions have experimented over the years with exhibits that make various computer-controlled devices accessible to the public. Common examples include voice synthesizers, tone generators, graphics terminals and plotters, and electromechanical "turtles."

Exhibits using voice synthesizers have allowed visitors to teach the computer to "speak" by putting together various combinations of English phonemes. Rusty Whitney, director of OMSI's computer center, has recently been exploring the idea of combining a voice synthesizer with a version of Joseph Weizenbaum's ELIZA program (computer-simulated Rogerian psychotherapist) and a vocabulary/translator program developed at Bell Labs so that OMSI



visitors could almost literally carry on a "conversation" with ELIZA.*

Similarly, Lawrence Hall of Science has an exhibit using a computer-driven tone generator—i.e., a simple electronic device for producing tones of various frequencies under computer control. The tone box, as it is called, is connected through a terminal in the exhibit. Using a suitable musical notation (e.g., the keys "C, D, E, F, G, A, B" on the terminal keyboard represent the notes DO, RE, ME, FA, SO, LA, TI of the musical scale, the space bar produces a rest, etc.), a visitor may compose a tune that the computer will store and play back on command. There are also options for playback with variations in tempo and pitch. LHS maintains a library of tunes "transcribed for computer tone box" by visitors and "special kids." These tunes may be requested by name at the terminal.

Graphics is another excellent way to introduce the power of computers to the public. Several different types of graphics devices have been used successfully in the museum environment. The least sophisticated and least expensive of these is the cursor-addressable, character-generating CRT terminal on which it is possible to selectively change one part of the screen while leaving the remaining display unaltered. Such CRT's allow a game such as Hangman to be programmed so that the "man" does not roll off the screen and have to be completely re-drawn each time a letter is incorrectly guessed. Rather, arms, legs, trunk, etc., are simply added with each missed letter until either the word has been guessed or the man is completely hanged.

Fully refreshable vector graphics CRT's or plasma displays with graphic input capabilities would be most desirable in the museum environment since they provide a quantum leap in power and flexibility, but such devices are still well out of the range of very limited museum exhibit budgets. The best compromise available to museums is the Tektronix storage tube graphics terminal, such as those being used at OMSI. These terminals have the advantage of being durable and low cost while providing both character and vector graphics with an option for graphic input. In most science centers and museums today, such terminals alone would provide a quantum leap in capability from the status quo.

Another type of device that has been used effectively in some science centers to introduce computers to young children is Seymour Papert's robot "turtle." To quote Sema Marks[4]:

> A turtle is a computer-driven supertoy. It can move forward or backward and can rotate around its center. A pen is attached to its center, and when the pen is down, the turtle draws a line wherever it goes.

Turtles are commercially available, although some museums have built their own from Meccano sets or from spare parts. The movement of a turtle may also be simulated on a graphics plotter or graphics terminal.

Using a programming language called LOGO, children learn to control the motion of the turtle, thus expanding their knowledge of what Papert calls "turtle geometry." Papert[14] feels that the experience of a program-controlled device can be used to "give children ... a sense of power of ideas in general, of science in particular and especially of mathematics." By learning to control the turtle, children master concepts such as planning, debugging, modular structure, modeling, and so on, thus giving them a "mathematical experience more like an engineer's than like a bookkeeper's." One may simply extend these ideas to the museum environment on the assumption that program-controlled devices can also give this sense of power to adults as well as children.

Computer Classes. Classes at science centers provide another way of increasing public awareness about computers, one that provides greater depth than might usually be achieved through exhibits. Most science centers offer afternoon, evening, or weekend classes in a variety of

* I say *almost* literally because voice recognition equipment and software are not so readily available as voice synthesis equipment; thus, the visitor would *type* his/her comments at a terminal and ELIZA would *talk back*, as it were.

Table 2. Computer classes offered at various science centers.

INSTITUTION	COURSE OFFERED	ENROLLMENT INFORMATION	COURSE DESCRIPTION
The Franklin Institute, Philadelphia	Computer Programming	Grades 8-10 6 Saturdays (9:30 to 11:30 plus laboratory time) Members $32, Non-members $35	Workshop emphasizes computer language. Once familiar with the APL terminal and language, students will understand how computer performs rapid calculations and stores information. They will play computer games and practice writing and testing their own programs.
Oregon Museum of Science and Industry, Portland	Pascal I—Computer Class for Beginners	Age 12 and up 6 Tuesdays (7 to 9 p.m. plus one-hour computer use) Enrollment limited to 12 students Members $25, Non-members $28	Pascal computer language, developed in Europe for educational use, will be taught to those who have some experience in math or math puzzles and ability to solve $5x + 17 = 3$ for the value of x. Students will use PDP-11/45 computer to test programs they have written.
	Pascal II—Intermediate Computer Programming	6 Wednesdays (6:30 to 9:30 p.m.) Members $30, Non-members $34	Continues Pascal I class, which is a course prerequisite.
	Pascal III—Advanced Computer Programming	6 Thursdays (6:30 to 9:30 p.m.) Members $30, Non-Members $34	Continues Pascal II class, which is a course prerequisite.
California Museum of Science and Industry, Los Angeles	Computers	Grades 5-8 4 Saturdays $15, plus $2 Lab Fee	Gather data on how the computer thinks, learn how to work the apparatus, and write programs using its special language. Challenge the computer to games that test your wits. Field trip to a computer research center included in the last session.
Fernbank Science Center, Atlanta	Introduction to Computer Programming	Four levels offered Student-adult, grades 7-12 Teacher In-service Elementary or High School Family 5 evenings (7:30 to 9:30) Registration Fee $6	Introduces students to computer programming in APL and gives them enough information to write complete programs for problem solving. At end of course, student will be able to continue with more advanced programming features on his own initiative.
Lawrence Hall of Science, Berkeley	Creative Play with the Computer	Age 8-11, grades 3 to 6 8 afternoons (4 to 5:30) Enrollment limited to 16 Members $42, Non-members $50	Explore computer as an artistic, expressive, and recreational medium. Learn to use teletypewriter and electronics graphics plotter. Other activities may include use of a computer-controlled musical tone box, cathode ray tube terminal, and a graphics display screen.
	Beyond Creative Play	Age 10-13, grades 5 to 8 8 afternoons (4 to 5:30) Enrollment limited to 16 Members $42, Non-members $50	Students learn problem-solving techniques that prepare them for beginning programming. Computer graphics and games will be included, but activities are directed toward learning how to write simple programs.
	Computer Science Seminar I	Age 13—adult, grades 8 to adult 8 afternoons (4 to 6) Enrollment limited to 12 Members $42, Non-members $50	Explore advanced topics in computer science on an interactive, small-group basis. Depending on experience of participants, activities may include machine organization, advanced programming languages other than Basic, and writing programs for specific applications.
	Pilot Your Own Computer	Age 10-16, grades 5 to 11 8 afternoons (4 to 5:30) Enrollment limited to 15 Members $42, Non-members $50	Learn to program in Pilot, a non-math computer program. Materials and instructional guidance help students to progress at their own pace, learning concepts that provide a good foundation for programming in Basic and other computer languages.
	Computer Programming in Basic	Age 10-18, grades 5 to 12 8 afternoons (4 to 5:30) Enrollment limited to 15 Members $42, Non-members $50	Class will be divided into small groups on basis of previous experience. Individual instruction within groups. New topics in Basic programming will be introduced and explored. With guidance of instructor, students will develop their own computer programs.
	Computer Exploration for Adults	8 evenings (7 to 9) Enrollment limited to 12 Members $32, Non-members $40	Not a programming class. Programming languages, computer systems, and computer hardware will be explained in understandable terms. Explore ways which computer affects daily life in terms of business, education, art, science, privacy, and law enforcement.

science-related subject areas. Such classes are most often taught by members of the institution's staff, are supported partly by tuition fees, and are usually informal or workshop-style, offered for enrichment rather than for credit.

Table 2 shows sample descriptions of computer courses offered at various institutions. Notice that most of the institutions listed offer only one course aimed mainly at students ages 11 and up. The descriptions generally emphasize learning basic computer concepts, playing games, and especially learning to program in APL, Basic, Pilot, or even Pascal. With the exception of Lawrence Hall's extensive offerings (Table 2), these classes would

best be categorized as another form of limited or special access in which a relatively small fraction of the general public has an opportunity to learn about computers in some depth and to learn a programming language. These courses are included in the description of Level II because they are available to the *general public* and not just to special school groups. Furthermore, a real need is for many more courses such as Lawrence Hall's "Creative Play with a Computer" (for 8-12 year-old children) and "Computer Exploration for Adults." These courses concentrate on what computers are, how they work, their uses and abuses, and how they affect the daily lives of people rather than concentrating on learning programming per se.

Three educational computing resource centers. Certain Level II institutions have made a sizable investment in computer resources; others with limited resources have at least attempted to make those resources available to the public. Three institutions, the Boston Children's Museum, OMSI, and LHS operate minicomputer timesharing systems on-site, thus assuming an entrepreneurial role not possible in most other institutions. All three of these centers have at least one staff member specifically dedicated to computer-related activities, and all three work closely with local schools. Indeed, one of the main functions of these institutions is serving as an educational computing resource center for local schools.

In addition, LHS is engaged in providing an educational timesharing service to local schools. The LHS computer system presently reaches more than 40 schools and educational institutions in Northern California including a Montessori school; elementary, junior, and senior high schools (both public and private); the California School for the Deaf; junior colleges; four-year colleges; and some departments on the UC Berkeley and UCLA campuses.

OMSI and the Children's Museum have more limited facilities for remote timesharing; thus they have concentrated their efforts on software development. Marketing of system software developed at OMSI for the PDP 11/45 has been one of the sources of revenue helping to support the OMSI computer center. All three institutions work with teachers in local schools to provide both computer programs and computer-based materials for use in the classroom.

To summarize Level II, General Public Access: science centers and museums at this level are making computer power openly accessible to the general public by placing computer terminals and computer-controlled devices in public exhibit areas and, to a small extent, by offering classes. The computer exhibits at Level II institutions are of an informal rather than formal nature. At Level I institutions, the power of the computer is formally demonstrated to an "audience" several times a day by a staff member of the institution; the terminal or device is not otherwise visible or available to the public. At Level II institutions, people may use the computer terminal (device) at their own pace and in their own manner. The exhibit is always accessible (at least when it is working). Classes, if offered at Level II institutions, are open to the general public — i.e., they are not just for school groups, and they are for adults as well as children. These distinctions are amplified and extended at Level III.

Level III: active community computer education

Between Level II and Level III there is a quantitative and qualitative difference. The foundations for achieving the goals of promoting public computer literacy and providing public access to computers have been well established in Levels I and II. The distinction between Level II and Level III is the degree to which an institution is actively concerned with community education. The Lawrence Hall of Science is a good example of a Level III institution. Of the 167,000 children and adults who visited LHS in 1975-76, more than 27,000 (16%) came specifically to gain access to computers.

Indeed, the main factor underlying Lawrence Hall's position in the model is the importance it ascribes to computer education. LHS has concentrated on three areas of science education in its public programs: (1) astronomy and physics, (2) biology and ecology, and (3) computers and mathematics. Over the past five years, the computer and mathematics area has enjoyed more than its equal share of priority for allocation of resources, development of facilities, and procurement of staff. Thus, the Lawrence Hall has put considerable thought and effort into building a computer education facility that would simultaneously meet the needs of public visitors, visiting school groups, classes and local schools, and the San Francisco Bay Area community.[8]

On a smaller scale, Lawrence Hall seems to reflect the philosophy of Dartmouth's president, John Kemeny,[11] who describes Dartmouth's computing facility as an intellectual resource for the community, like a library, where computer power is freely accessible to the community. Over the past six years, LHS has defined three major objectives for its computer education program:

(1) to educate children and adults about the milieu of computers in an enjoyable, intriguing, non-threatening learning environment;

(2) to offer the public hands-on computing at low cost;

(3) to develop an exportable educational program of computer activities that will serve as a resource for schools and other learning centers and public educational institutions.

LHS has attempted to meet these objectives through many of the same programs and activities described in Levels I and II, but on a larger scale. Several terminals (including the computer-controlled tone generator) are openly accessible to visitors in the exhibit area. Some of these terminals, using a monitor program like the one described earlier, present a selection of programs from various categories of the "standard repertory." Two terminals form an integral part of a new exhibit on energy uses and alternative sources. These terminals allow visitors to manipulate variables in energy-use simulations with the goal of conserving energy while maximizing some other desirable quantity.

As noted earlier, LHS has an extensive program for visiting school children, and the Hall's two computer terminal rooms assure that each individual student receives a maximum amount of hands-on experience in the computer laboratory. The two computer terminal rooms are also used for after-school and in-service classes and for public computer access. As shown in Table 2 LHS offers a complete series of computer classes (to more than 1000 children and adults) throughout the year. The courses are designed to meet the needs and abilities of students young and old. They cover topics from computer literacy for children and adults to programming and theoretical and applied topics in computer science.

Besides these exhibits, courses, and workshops, which provide limited or structured access, LHS also offers unstructured access to computers. People who simply wish to sit down at a terminal and execute any program

of their choosing from the program library or even write their own programs (often exercising skills previously learned in workshops and classes) may do so on the weekends, Thursday evenings, and Friday afternoons. At these times, Lawrence Hall opens one or both of its computer-terminal rooms to the public at a cost of $1.50 per hour.

Furthermore, Lawrence Hall has allocated some ports on its timesharing system for home use by its members at a monthly rate comparable to its educational rate; a much lower rate is available to members wishing home access restricted to evening and late night hours.

In summary, Level III represents an active campaign by a science center to educate the members of its community about the power of personal computing. This level provides for increased public awareness of computers in an informal learning environment; it also offers options for more in-depth, formal learning through classes. Most important, it offers an opportunity for personal exploration of interactive computing through freely accessible but structured exhibits and through direct, unstructured, self-motivated hands-on access, including access to individuals in the privacy of their own homes. For the mid-1970's, this represents a large step toward making computer power available to the community.

Level III represents a model for institutions striving to go beyond providing public access to assuming an active role in public education. As a public service unit of the University of California, the Lawrence Hall of Science is well-suited to this role. However, Lawrence Hall is also an educational research unit of the Berkeley campus, and in this regard, it aspires to a fourth level in the model.

Level IV: ideal public access computing center

As yet, there are no institutions exemplary of Level IV. This level augments the community education center of Level III with an educational research and development component. Such institutions would require considerably more funding than those at lower levels to support this extra component. Thus, they would be few in number and most likely be affiliated with universities or, perhaps, with government- or corporate-funded educational research institutes. Level IV represents a goal that has not yet been realized at LHS, but it is the next step.

Basic research needs. The remainder of this article poses more questions than it answers. Level IV institutions need to investigate whether current public computer education and access endeavors are worthwhile, and if they are not, how these endeavors should be altered. There is a general need among public access centers at all levels for evaluation of current activities and basic research regarding the nature of the interaction between people and computers and ways in which people perceive computers after interacting with them. More specifically, the following two sets of questions are representative of such current research needs:

(1) How does spending time at a computer terminal affect people's attitudes regarding computers? Is there a qualitatively different effect on people who spend a few minutes at an exhibit terminal versus those who buy a ticket to use the computer for an hour? What effects do computer-related classes have on people's attitudes?

(2) Is a game-playing computer terminal in an exhibit area a worthwhile use of computer resources? How does the experience of playing games on a computer terminal in a science center differ from such an experience in an electronic arcade? Do game-playing computer exhibits lead people to have misconceptions about computers? What social function do computer games fulfill?

Another set of research questions addresses the problem of how computers might best be used in various environments. For example:

(1) How should computers be integrated into other exhibits in the museum or science center? What type of information is best presented by a computer in the museum environment?

(2) How might schools best make use of computer power? At what stage of development should children be introduced to programming, and what programming languages are suitable for this purpose? Does learning a programming language lead to increased problem-solving skills or logical thinking?

(3) What are the pros and cons of providing computer power to the community at large (e.g., creating data-bases and placing terminals in public places such as libraries, supermarkets, post offices, etc.)?

This is only a small sample of the many research questions that could be asked. While the current state of knowledge in the computer industry is exploding, the knowledge concerning the human/computer interaction and public use of computers is limited. Since science centers deal with the general public, they provide an ideal environment for researching these questions.

Future public access. Computer power is beginning to move into the public domain at a personal level. Pocket-sized electronic calculators are already so mundane as to be sold in supermarkets, and programmable pocket calculators and video games are standard merchandise in department stores, discount houses, and mail-order catalogues. Within the next few years, general purpose microcomputers will undoubtedly begin to follow a similar path into the home. Whether personal computers will be used fully and wisely to enrich the quality of human life or whether they will be used frivolously—or even misused—will depend to a large extent on how well people understand the power and the limitations of such machines.

The modern science-technology center is a place where general impressions of scienctific and technological ideas are formed; it is a place which arouses people's curiosity about science and technology and offers people an opportunity to explore technological gadgets. Indeed, the science center *potentially* is an ideal place for discovering and exploring the power of computers at a personal level. The model developed throughout this paper characterizes and relates the efforts currently being made at a few science centers in this regard.

In the near future, such public access centers should also become publicly accessible showcases for the latest computer technology, and they will have the responsibility to develop model software, broader in scope than mere amusement. In fact, they should become a community information resource, program library, and data bank from which persons may ask advice, borrow programs, or retrieve information for use on their home computers. Finally, while providing these public services, the ideal public access center will attempt to answer research questions concerning the nature of the human-computer interaction and develop creative and productive ways to harness computer power for the benefit of mankind. ■

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As part of a Master's project, Kahn developed an introductory computer course offered by the Lawrence Hall of Science for 8-10 year old children. He is currently interested in understanding, evaluating, and facilitating informal learning—i.e., learning in non-school settings such as museums and zoos or learning that occurs while browsing or playing.

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